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THE OPPORTUNITIES OF CHANGING FROM OIL HEATING TO DISTRICT HEATING

Case: Interview survey in the Lahti region

LAHTI UNIVERSITY OF APPLIED SCIENCES
Faculty of Technology
Degree Programme in Environmental Technology
Master’s Thesis
Spring 2015
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ASIKAINEN, TARJA:

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Master's thesis in Environmental Technology, 61 pages, 15 pages of appendices

Spring 2015

ABSTRACT

This research focused on heat generation and procurement in the old residential areas in the Lahti region. Heat generation causes harmful impacts on the environment, which are mainly formed from burning fossil fuels. The storage of heating oil also causes a risk for soil and groundwater pollution. The aim of the Finnish energy policy is to increase the share of renewable energy sources in energy generation, and the long-term objective is a carbon neutral society by 2050. People can promote sustainable development with their choices and decisions. Decentralized heat generation, such as oil heating, is widely used in urban residential areas, also in areas supplied with district heating.

This case study was executed with the cooperation partner Lahti Energy Ltd. The thesis studied oil-fired property owners' perceptions and understanding concerning district heating. The opportunities of changing from oil heating to district heating were also inquired. The survey was carried out by telephone with the response rate of 79 %. In all, 61 oil-fired property owners next to the district heating network were interviewed in 2014. The oil-fired detached houses, located in the survey areas in Lahti and in Hollola, were mainly built in 1960s and 1970s.

Most of the respondents valued district heating as a carefree, safe and reliable heating method, as well as being more environmentally friendly than oil heating. 77 % of the oil tanks in this study were over 30 years old, and therefore at the end of the technical useful life. Only 16 % of the oil-fired heating systems had been totally renewed, instead oil boilers had been renewed a lot. Some respondents were interested in district heating. The lack of an interest was mainly caused by an expensive investment with a long repayment period. People's perceptions are not in all cases identical with the reality. Calculations were used to compare the annual costs and the investment costs of the heating systems. According to the calculations in this thesis, district heating is a competitive heating system for oil-fired properties supplied with an old oil boiler. Furthermore, oil heating supplied with an old oil boiler causes nearly two times more CO_2 emissions than district heat generation in the Lahti region. The multifuel power plant, which will be in use in 2021, is designed to use mainly renewable energy sources, which promotes the long-term goal towards sustainable development.

Keywords: cost-effectiveness, district heating, energy efficiency, fossil fuel, greenhouse gas, household, oil heating, oil accident, oil spill, renewable energies

Lahden ammattikorkeakoulu
Ympäristöteknologian koulutusohjelma (YAMK)

ASIKAINEN, TARJA:

Kaukolämpö vaihtoehtona öljylämmitykselle
Haastattelututkimus Lahden seudulla

Ympäristöteknologian koulutusohjelman opinnäytetyö (YAMK), 61 sivua, 15 liitesivua

Kevät 2015

TIIVISTELMÄ

Tässä tutkimuksessa tarkasteltiin lämmöntuotantoa ja -hankintaa vanhoilla asuinalueilla Lahden seudulla. Lämmöntuotanto aiheuttaa haitallisia ympäristövaikutuksia, joita muodostuu pääasiassa fossiilisten polttoaineiden polttamisesta. Lämmitysöljyn varastointi aiheuttaa myös riskin maaperän ja pohjaveden pilaantumiselle. Suomen energiapolitiikan tavoitteena on lisätä uusiutuvien energialähteiden osuutta energiantuotannossa pitkän aikavälin tavoitteen ollessa hiilineutraali yhteiskunta vuoteen 2050 mennessä. Ihmiset voivat edistää kestävää kehitystä valinnoillaan ja päätöksillään. Hajautettu energiantuotanto, kuten öljylämmitys, on laajasti käytössä myös kaukolämpöön liitetyillä asuinalueilla.

Tämä tapaustutkimus toteutettiin yhteistyössä Lahti Energia Oy:n kanssa. Opinnäytetyössä tutkittiin öljylämmitteisten kiinteistönomistajien käsityksiä ja mielikuvia kaukolämpöön liittyen. Lisäksi selvitettiin kiinteistöjen kiinnostusta siirtyä öljylämmityksestä kaukolämpöön. Haastattelututkimus tehtiin puhelimitse vastausprosentin ollessa 79 %. Vuonna 2014 haastateltiin yhteensä 61 öljylämmitteisen kiinteistönomistajaa, jotka asuivat kaukolämpöverkon varrella. Tutkimusalueilla Lahdessa ja Hollolassa sijaitsevat öljylämmitteiset omakotitalot oli rakennettu enimmäkseen 1960- ja 1970-luvuilla.

Suurin osa vastaajista piti kaukolämpöä huolettomana, turvallisena ja luotettavana sekä ympäristöystävällisempänä lämmitysmuotona verrattuna öljylämmitykseen. Tutkimusalueiden öljysäiliöistä 77 % oli yli 30 vuotta vanhoja, eli teknisen käyttöikänsä päässä. Öljylämmitysjärjestelmistä vain 16 % oli täysin uusittu, sen sijaan öljykattiloita oli uusittu paljon. Muutama kyselyyn vastanneista oli kiinnostunut kaukolämmöstä. Kiinnostuksen puutetta perusteltiin enimmäkseen investoinnin kalleudella ja pitkällä takaisinmaksuajalla. Ihmisten käsitykset eivät aina vastaa todellisuutta. Lämmitysjärjestelmien vuosi- ja investointikustannuksia vertailtiin laskelmilla: kaukolämpö on kilpailukykyinen lämmitysmuoto kiinteistöllä, joissa on käytössä vanha öljykattila. Lisäksi vanha öljykattila aiheuttaa lähes kaksinkertaisesti CO_2-päästöjä verrattuna kaukolämmön tuotantoon Lahden seudulla. Vuonna 2021 valmistuva monipolttoainevoimalaitos on suunniteltu toimivaksi pääasiassa uusiutuvalla energialla, mikä edistää pitkän aikavälin kestävän kehityksen toteutumista.

Avainsanat: kannattavuus, kaukolämpö, energiatehokkuus, fossiilinen polttoaine, kasvihuonekaasu, kotitalous, öljylämmitys, öljyvahinko, öljyvuoto, uusiutuva energia

CONTENTS

1 INTRODUCTION

1.1 Background

This study is focused on heat procurement in old residential areas in the Lahti region. Heat generation causes harmful impacts on the environment, which are mainly caused by burning fossil fuels and the storage of heating oil. There are large groundwater areas in the Lahti region, therefore groundwater is protected by the municipal environmental regulations, in addition to the legislation.

The aim of the Finnish energy policy is to increase the share of use of renewable energy sources in energy generation, and the long term objective is to have a carbon neutral society by 2050 (Ministry of Employment and the Economy 2013, 7-11). People can promote sustainable development with their decisions when choosing a heating system. Cost-effectiveness and economy in heating costs are considered as significant aspects in the decision-making process in new building projects, as well as in renovating heating systems. Furthermore, the environmental friendliness of energy generation is even more and more important for consumers.

This thesis studies the opportunities of changing from oil heating to district heating in the Lahti region. The aim is to examine environmental impacts and financial aspects of both heating systems. The main survey group is chosen from old residential areas, where oil heating is still widely in use. Especially old underground oil tanks and related equipment cause an actual threat to the environment. The old underground oil tanks were manufactured mainly from metal. Nowadays, oil tanks, made from fibreglass or reinforced plastic, have become more frequent. Also, the capacities of oil tanks have decreased.

Oil spills are mainly caused by corrosion, or from broken oil pipes located underground. Oil accidents occur during the filling of oil tanks. As the result of an oil spill, soil is polluted. At the worst, oil spills as well as oil accidents may cause groundwater contamination. Plastic tanks also cause risk, particularly if pipe joints are damaged or pipes are wrongly dimensioned.

Oil is classified as a fossil fuel, and, therefore, the burning of oil causes greenhouse gas (GHG) emissions. The advantages of district heating are mentioned, especially the use of different fuels in heat generation. Depending on the burning and boiler technologies, and the prices of the fuels, district heating is generated by renewable fuels, fossil fuels, or combining fossil and renewable fuels.

The cooperation partner in this study is the local energy company Lahti Energy Ltd, whose main line of business is combined heat and power generation. The district heating network covers extensive areas of the city of Lahti and the neighbouring municipalities.

In this thesis, a limited number of oil-fired property owners in the Lahti region are interviewed. The most potential survey group for the interviews is located in the old residential areas, supplied with the district heating network, where a low number of properties connected to the district heating network exist. The focus is to find the households living in detached houses and supplied with oil heating.

One of the main questions will deal with oil-fired property owner’s interest to replace oil heating with district heating and discuss the reasons, if the replacement is not an interesting alternative, or a topical issue at the moment. Some basic questions concerning oil heating and the maintenance of oil heating will also be asked, as well as the environmental aspects of district heating compared with oil heating. All contact details of the interviewees will be treated in confidence.

Calculations, related to economy and greenhouse gas (GHG) emissions between oil heating and district heating, will be drawn up to find out possible differencies. Also, by drawing calculations, it is possible to compare the survey groups’ perceptions and understanding of the reality. The objective is also to examine the city planning processes, and Lahti Energy Ltd’s opportunities to influence the energy procurement in the planning process. Furthermore, the objective is to review the goals which have been set locally to reduce the impacts on climate change.

1.2 Research questions and the aim of the study

The objective is to study the opportunities and the interest of the property owners to change the existing oil heating to district heating. The target group was chosen from the city of Lahti and the municipality of Hollola. The survey questionnaire was planned together with Lahti Energy Ltd. The main research questions that influenced the choice of the topic, were as follows:

1. Why is oil heating still widely used in Finland?
2. Why would district heating be a more interesting choice compared with oil heating?
3. What are the limitations when expanding the district heating network in the Lahti region?
4. How do city planners deal with energy procurement during the planning process concerning new and existing areas?
5. Does the energy company have opportunities to influence the planning process in the Lahti region?

In this thesis, the aim is to review the environmental impacts that the changing of an oil heating system to district heating has on the environment. Also, it is necessary to study the legislative requirements and the regional environmental protection regulations concerning oil tanks and energy procurement.

1.3 Key concepts

CHP

CHP means combined heat and power production, where backpressure or bled steam is utilised as district or process heat. Combined production involves electricity generation in an engine or a gas turbine-operated production machinery, where the heat from the exhaust gases or the cooling water is used as an energy source. Higher efficiency ratios are achieved with combined production than with separate production. In practice, this means that the fuels needed in the production are used more efficiently. (Statistics Finland 2015a.)

Climate change

Climate change means unexpected and harmful changes in the climate affecting nature, economy and human health. The temperature is rising, heavy rain causes stormwaters, rainfall increases, glaciers and snow are melting, as well as global sea level is rising. The most feasible explanation for climate change has been observed as the increase in GHG emissions. (European Environment Agency 2015.)

EU ETS

EU ETS means the EU Emissions Trading System. The EU ETS is applied to 31 countries in the European region. The target is to reduce greenhouse gas emissions cost-effectively. Over 11 000 heavy energy-using industrial sites and power generation sites (later: operators) are involved in the EU ETS, as well as the airlines. The EU ETS was started in 2005. The action periods are as follows: Phase 1 (2005 – 2007), Phase 2 (2008 – 2012) and ongoing Phase 3 (2013 – 2020). (European Commission 2014a.) Airlines are involved with the EU ETS since 2012. Flights within and between countries are included in the EU ETS. International flights to and from non-ETS countries are also covered. (European Commission 2014b.)

One essential part of the EU ETS involves an independent verification process, where annual emission reports of operators are reviewed. The researcher of this study has eight years' experience as the reviewer in the verification team of Enemi Ltd during Phases 1 and 2.

All the installations that belong to EU ETS, have emission permits and annual emission allowances for free. In the case where the annual emission allowances are exceeded, the company is obligated to bye extra allowances from the emission trade market. (Ministry of Employment and the Economy 2014b.) Another way to stay within the emission allowances is to use more renewable fuels, or shut down the operations till the end of the monitoring period.

Fossil fuels

Fossil fuels are fuels, that were formed from biomass and stored underground millions of years ago (Statistics Finland 2015b). Fossil fuels are not renewable natural sources. According to the fuel classification, fossil fuels are petroleum products such as aviation gasoline, heating fuel oil, diesel oil, heavy fuel oil, coal, natural gas and peat (Statistics Finland 2015c). Also, non-renewable fuels are nowadays used as a synonym for fossil fuels.

GHGs

GHGs mean greenhouse gases. GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs) (Regulation EU No 525/2013, Annex 1). The EU ETS covers CO_2, N_2O and PFCs. CO_2 emissions are mainly originated from power and heat generation, commercial aviation and a wide range of energy-intensive industry sectors. N_2O are originated from the production of certain acids and PFCs from aluminium production. (European Commission 2014a.)

TANKKI project

TANKKI project means the EU funded TANKKI oil tank risk project, which was implemented in the Häme region in 2012 – 2015, managed by Lahti University of Applied Sciences. Altogether eight municipalities, two cities, the Kanta-Häme and Päijät-Häme rescue departments, Häme University of Applied Sciences, and the Centre for Economic Development, Transport and the Environment of Häme (ELY Centre) participated in the project. (TANKKI hanke 2015.)

The aim of the project was to reduce soil and groundwater pollution caused by oil spills or oil accidents. The knowledge of the duties of oil tank owners was increased during the project by advising them. An electronic risk management tool was developed as the advisory material, as well as a guidebook for the oil tank owners. Furthermore, less used soil remediation methods (in situ methods) were tested at three sites that were contaminated by heating oil. (TANKKI hanke 2015). The researcher of this study was responsible for implementing the project from August 2013 until the end of the project, March 2015.

2 PROVIDING HOUSEHOLDS WITH HEAT

In this chapter, a general overview of the share of energy consumption, and the used energy sources in households in Finland, as well as legal and other requirements concerning oil heating and district heating are presented. The review aspect is focused on environmental protection, on the steering tools and energy efficiency. Especially the legal requirements concerning oil tanks and oil heating are reviewed in more detail.

2.1 The consumption of heating energy in households

Finnish energy policy is based on the National Energy and Climate Strategy, approved by the Government in March 2013. The goal of the strategy is to obtain the EU's Energy and Climate Policy targets which have been set until 2020. In practice, the targets have been focused on reducing GHG emissions by 20 %, on raising the share of renewable energies by 38 % and on improving energy efficiency by 20 %. According to the Government Programme, the long term goal is a carbon neutral society by 2050. (Ministry of Employment and the Economy 2013, 7-11.)

Due to Finland's geographical location a significant share of final energy consumption goes into the heating of buildings, 25 % in 2013 (Motiva Oy 2015a). In this thesis, the research is focused on the households' interest to change from oil heating to district heating. In this context, it is reasonable to review what kind of changes can be detected in the final energy consumption of the households by fuel.

The share of the energy sources in households by fuel in 2004 – 2013 is presented in Figure 1. The same data is presented in numbers in Appendix 1. According to the Eurostat's classification, energy sources have been categorized into six products according to the origin and the generation. The main change has occurred in the consumption of total petroleum products within ten years: the consumption decreased significantly (from 14 % to 8 %). The share of renewable energies increased from 22 % to 25 %, and the share of derived heat increased from 29 % to 31 %. Gas consumption has remained under 1 %. The use of solid fuels was minor, therefore the share is not observed in the bar chart. Electrical energy consumption includes the total energy use in the households. (Statistics Finland 2015d.)

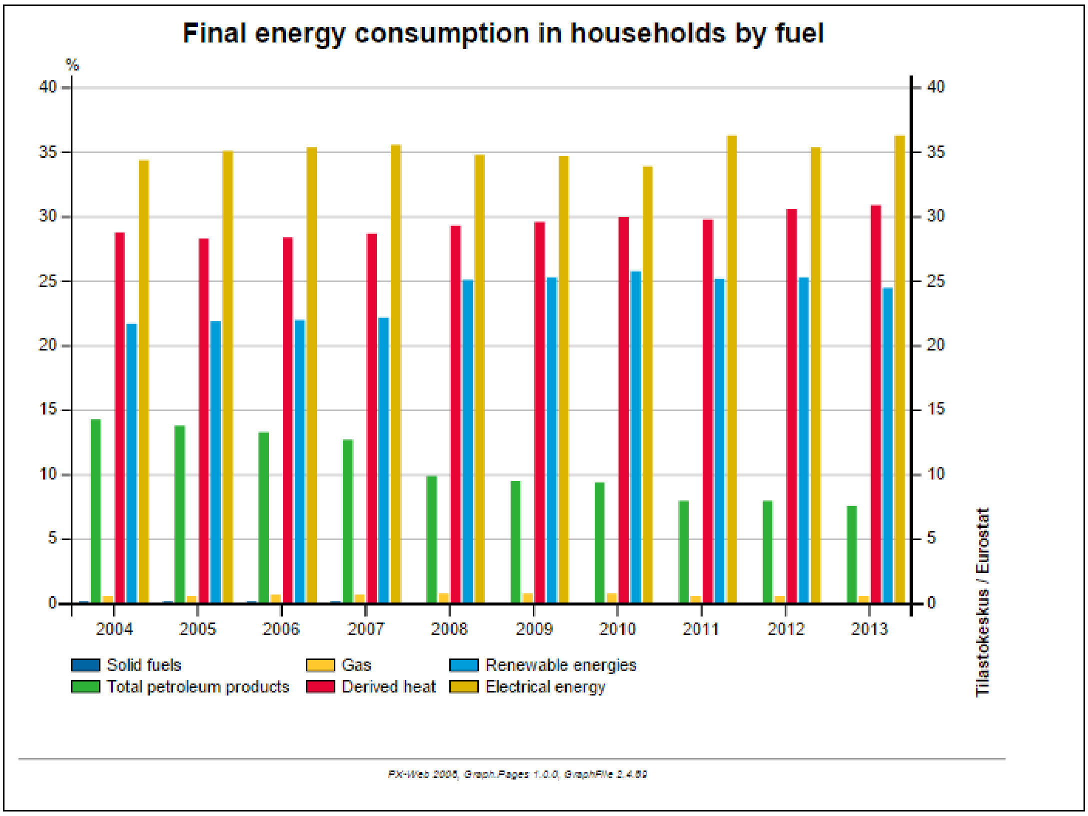

FIGURE 1. Share of final energy consumption in households by fuel 2004 – 2013 in Finland, % (Statistics Finland 2015d).

The fuel classifications of Eurostat and Statistics Finland differ from each other, therefore the definitions of solid fuels and renewable energies are clarified as follows:

- Solid fuels include solid fossil fuels such as hard coal, coal patent fuels, coke, coal tar, lignite, browncoal briquettes and peat briquettes, peat and oil sands (European Commission 2014c, 256).

- Renewable energies include fuels such as hydropower, wind energy, solar thermal, solar photovoltaic energy, geothermal energy, wood, wood waste, biogas and biofuels (European Commission 2014c, 255).

- Derived heat is a synonym for district heating and is defined as follows (Eurostat 2015):

> *Derived heat covers the total heat production in heating plants and in combined heat and power plants. It includes the heat used by the auxiliaries of the installation which use hot fluid (space heating, liquid fuel heating, etc.) and losses in the installation/network heat exchanges. For autoproducing entities (= entities generating electricity and/or heat wholly or partially for their own use as an activity which supports their primary activity) the heat used by the undertaking for its own processes is not included.*

According to Statistics Finland, the most significant methods of energy generation were district heating (33 %), wood (26 %) and electricity (24 %) in households in 2013. Other widely used energy sources were light fuel oil (heating oil, 8 %) and ambient energy (8 %), which means that energy was produced by heat pumps. All used heat energy sources, in total and separately by household types in 2013, are presented in Table 1. (Statistics Finland 2015e.)

When looking at the heat energy consumption of the detached houses, two significant energy sources were wood (40 %) and electricity (30 %). The use of ambient energy and light fuel oil were at the same level (ambient energy 12 % and light fuel oil 11 %), while district heating had minor importance as the energy source (7 %) in the detached houses, whereas district heating was the principal energy source in blocks of flats (86 %).

Free-time residential buildings were heated mainly by wood (64 %), but also ambient energy and light fuel oil have been reported as the energy sources. District heating has a marginal position in free-time buildings, due to the infractructure. The distribution of heating energy consumption, calculated in percentages, is presented in Appendix 2.

TABLE 1. Heat energy consumption in households by energy source in 2013, GWh (Statistics Finland 2015e).

	Heating of residential buildings, Total GWh	%	- Detached houses	- Terraced houses	- Blocks of flats	Free-time residential buildings
Wood	14502	26.3 %	12571	149	90	1692
Peat	49	0.1 %	42	1	5	1
Coal	3	0.0 %	3	-	-	0
Heavy fuel oil	87	0.2 %	-	-	87	-
Light fuel oil	4357	7.9 %	3432	278	595	52
Natural gas	336	0.6 %	99	77	159	1
Ambient energy 1)	4262	7.7 %	3757	358	30	117
District heating	18311	33.2 %	2053	2884	13372	2
Electricity 2)	13233	24.0 %	9536	1791	1134	772
Total	55140	100 %	31493	5538	15472	2637

Explanation of symbols: - = Magnitude zero, 0 = Magnitude less than half unit employed

1) Ambient energy refers to energy extracted with heat pumps from the environment (ground, air or water) for space heating. Electricity used by heat pumps in heating and cooling use is included in the electricity consumption of heating.
2) Electrical heating of residential buildings includes direct electrical heating, electric storage heating, additional heating and floor heating by electricity, the electricity used by heat pumps, the heating of domestic water by electricity, electric sauna stoves and the electricity consumed by the heating systems and the heat distribution equipment.

2.2 Legal and other requirements

In this context, legal and other requirements are examined from the point of view of environmental protection and supervision. Only property owners’ duties and obligatory actions are reviewed in detail.

2.2.1 Oil heating

Oil heating causes a risk for soil and groundwater, therefore periodic inspections of underground oil tanks are obligatory, if an oil-fired property is located in a groundwater area. Legislation concerning the obligatory inspections of the oil tanks entered into force in 1983. According to the decree (344/1983), all underground oil tanks, located in groundwater areas, have to be inspected even if they have been taken in use before the decree (344/1983) came into force in 1983. The first inspection should be carried out within ten years after taking an oil tank in use. The next inspection time depends on the classification of the tank, which is defined in the previous inspection (Table 2). (Kauppa- ja teollisuusministeriön päätös maanalaisten öljysäiliöiden määräaikaistarkastuksista 344/1983, Sections 1, 5-10.)

Environmental protection regulations have been issued by the municipal councils of Lahti and Hollola to take into account the local circumstances and the needs for environmental protection. Large groundwater areas are located in the city of Lahti, 37 % of the total surface area is classified as groundwater area. Respectively, 17 % of the surface area of the municipality of Hollola is classified as groundwater area. (Lahti 2015.)

Groundwater protection has been improved by regulating obligatory inspections and municipal environmental protection regulations (Table 2). All oil tanks should be inspected within ten years after taking an oil tank in use. An owner or a holder of an oil tank is responsible for the implementation of an inspection. Inspections of underground oil tanks are only allowed to be carried out by inspection bodies who have been accepted by the Finnish Safety and Chemical Agency (Tukes 2013). All oil tanks, regardless of the installation place in the property, have to be inspected by an accepted inspection body. (Environmental protection regulations of Hollola 2011, Sections 16 and 17; Environmental protection regulations of Lahti 2012, Sections 16 and 17.)

An inside covering of metals tanks is not allowed after the environmental protection regulations came into force. New oil tanks are not allowed to be installed under the ground in groundwater areas. When replacing an old oil tank with a new one, it must be installed in a building. (Environmental protection regulations of Hollola 2011, Sections 16 and 17; Environmental protection regulations of Lahti 2012, Sections 16 and 17.)

New oil tanks are always recommended to be installed above the ground, even if the proterty is not located in a groundwater area, because of better maintenance and inspection possibilities (Asikainen & Kärnä 2014, 15). The renewals and the decommissions of the oil tanks are supervised by the rescue authorities: the adjustment work must be reported by the oil tank owners (Päijät-Häme rescue department 2014a).

TABLE 2. Inspection periods of the oil tanks in the city of Lahti and in the municipality of Hollola (Decree 344/1983; Environmental protection regulations of Hollola 2011, Section 17; Environmental protection regulations of Lahti 2012, Section 17).

Classification	Underground oil tanks located in important groundwater areas (Decree 344/1983)	Oil tanks located in other places *, Lahti	Oil tanks located in other places*, Hollola
A	Metal tanks 5 years, Other tanks 10 years	10 years	10 years
B	2 years	5 years	5 years
C	Oil tank has to be taken out of use within 6 months	Oil tank has to be taken out of use within one year	Oil tank has to be taken out of use within one year
D	Oil tank has to be taken out of use immediately	Oil tank has to be taken out of use immediately	Oil tank has to be taken out of use immediately
Oil tank covered from inside	5 years	5 years	5 years

* In groundwater areas: All tanks located above the ground, inside a building, or in an underground bunker. Areas located outside of the groundwater area: All tanks located under the ground, above the ground, inside a building or in an underground bunker.

Metal tanks are classified according to the depth of the wall corrosion, and in case of other tanks (in practice plastic tanks) according to the impermeability. A –class metal tank means that the thickness of the wall is at least 3 mm and concerning plastic tanks they are found to be impermeable. Deeper corrosion has been detected in B – and C –class metal tanks. The worst situation applies to the D –class tank because there is one or more punctures in the walls, or the plastic tank is leaking during the leaking test. Furthermore, the inspection procedure and the content of the inspection report are defined in the legislation. (Decree 344/1983, Sections 1, 5 and 10.)

The renewal of an unsound oil tank (C –class) should be organised immediately because the tank must be taken out of use within 6 months in the groundwater areas, and in other areas within one year. If the oil tank is observed to be punctured or is leaking (D –class), it is not allowed to be used after the inspection. Oil, which has been removed from the tank before the inspection, cannot be pumped back to the leaking tank. (Table 2.)

2.2.2 District heating

District heating is a safe energy form for property owners in relation to its environmental risks. There are no environmental protection requirements concerning the construction and the maintenance of district heating and related equipment in households.

The local detailed plan steers building and other land use, as required by the local conditions. Regulations, issued in the local detailed plan, concern actions to prevent or reduce harmful environmental impacts. The obligation on joining a district heating network is stated in the local detailed plan. The obligation on joining is applied to the building in the building permit phase, if the district heating network connection is located in an immediate vicinity of the building site. The obligation on joining is not applied to the building whose main heating system is based on renewable energy sources with low emissions, or to the renewal of heating systems. (Land Use and Building Act 132/1999, Sections 50, 57 and 57a.)

Cooperation between the Lahti city planning and Lahti Energy Ltd is regular when planning land use. Planning meetings are held yearly in spring and autumn where the suitability of the planning areas and the sites for district heating are handled. Representatives of the city of Lahti, Lahti Aqua Oy, LE-Sähköverkko Oy and Lahti Energy Ltd participate in the planning meetings. Profitability calculations to connect the planning areas and sites to the district heating network are carried out by Lahti Energy Ltd. The decision of building a new district heating network is resolved according to the profitability calculations. Discussions with the land use services of the municipality of Hollola are not implemented regularly. District heating is less economical business expecially in new and sparsely populated detached house areas where buildings are energy efficient. (Wallin 2014e.)

2.2.3 Energy efficiency

Energy efficiency means a goal to promote the efficient use of energy in buildings, as well as the efficient use of fuels in energy generation. Within the EU, the goal is an 20 % increase in energy efficiency by 2020. For example, energy co-generation in CHP plants enhances the use of fuels. This means that by using less fuels more energy is produced. Energy efficiency increases the cost-effectiveness and the self-sufficiency in the energy supply, and decreases GHG emissions. Finland is one of the leading countries in the world in implementing cost-efficient solutions. (Ministry of Employment and the Economy 2014a.)

The use of renewable energy sources mitigates climate change and increases the eco-efficiency of the buildings. Climate change is a global concern, and therefore the EU has put efforts to decrease GHG emissions in energy generation. (The RES directive 2009/28/EY.)

The purpose of the RES directive (2009/28/EY) is to promote the use of renewable energies in the buildings. Member States have to implement the requirements concerning article 13 subsection 3 (the RES directive 2009/28/EY, 13):

> *Member States shall recommend to all actors, in particular local and regional administrative bodies to ensure equipment and systems are installed for the use of electricity, heating and cooling from renewable energy sources and for district heating and cooling when planning, designing, building and renovating industrial or residential areas. Member States shall, in particular, encourage local and regional administrative bodies to include heating and cooling from renewable energy sources in the planning of city infrastructure, where appropriate.*

In Finland, the implementation of the RES directive was studied in 2014 by a work group appointed by the Ministry of Environment (later the MoE). According to the proposal of the work group, the MoE has decided to continue the preparation of the building legislation towards low energy or zero energy building. (Ympäristöhallinto 2015a.)

Energy certificates, environmental permits and voluntary energy agreements are considered to be steering tools for increasing the energy efficiency of the buildings (Ympäristöhallinto 2015b). Environmental permits and voluntarily agreements are not applied to detached houses. Energy certificates are widely applied to different kinds of buildings, such as to residential buildings over 50 m^2 covering detached houses, to terraced houses and to blocks of flats. An owner is responsible for supplying an energy certificate. The total energy consumption of the building is determined by weighing the deferred purchase of the energy consumption with spesific energy coefficients. The energy certificate is valid ten years. The act came into force on 1 June 2013. (Act on Energy Certificates for Buildings 50/2013, Sections 2-10 and 28.)

The specific energy coefficients of energy forms are follows: electricity 1.7; district heating 0.7; district cooling 0.4; fossil fuels 1.0 and renewable fuels used in the building 0.5 (Valtioneuvoston asetus rakennuksissa käytettävien energiamuotojen kertoimien lukuarvoista 9/2013, Section 1). According to the energy coeffient values, a building supplied with district heating is more energy efficient compared with a building supplied with oil heating. Furthermore, energy efficiency can be increased by insulating old buildings and by planning low-energy or zero-energy buildings. New energy generation technologies enable electric energy sales to the grid.

3 HEAT GENERATION

In this context, heat generation is reviewed from the point of view of oil heating and district heating. The review aspect of other alternative methods is focused on the changing of oil heating to another heat generation system. District heat generation is reviewed from the point of view of Lahti Energy Ltd's operations.

3.1 Decentralized heat generation

3.1.1 Oil heating

There are estimated to be 210 000 oil-fired residential buildings in Finland at the moment. Detached houses form the major share of these properties, about 204 000. A number of oil tanks in the residential buildings is higher, 242 000, due to the changing of heating systems. (Otronen 2015.) In practice, this means that a high-capacity oil tank (typical capacity 3 – 5 m^3) has been changed to two or more smaller plastic tanks which are connected in series.

There are estimated to be 1400 oil-fired detached houses in the city of Lahti and 700 in the municipality of Hollola in 2014. The estimations are based on the Merlot register, maintained by the Päijät-Häme rescue department. (Heikkinen 2015.) The register includes all oil tanks in use, therefore the register was sorted by selecting all oil tanks, whose capacity was at the most 5 m^3, and the location was inside the building, inside the underground bunker, and installed directly inside the ground without the bunker. Furthermore, the tanks connected in series have been taken off, in order to get the real number of the oil-heated properties. One tank per property was counted to the estimations.

A construction of oil heating consists of two main elements: an oil boiler and an oil tank. Hot water is circulated in the water circulation system between radiators and an oil boiler, or underfloor heating pipes. The oil boiler is located in a separate boiler room. The oil tank is installed in the boiler room (Figures 2 and 3) or under the building, or outside, depending on suitable free space inside the building. In the case of older buildings without a basement, the oil tank is installed either in an underground bunker (Figure 4) or directly into the ground without any protection structures.

FIGURE 2. Old metallic oil tank is located in the basement. Brick wall has been built around the oil tank to prevent oil leakage. (Photo: Teija Tohmo.)

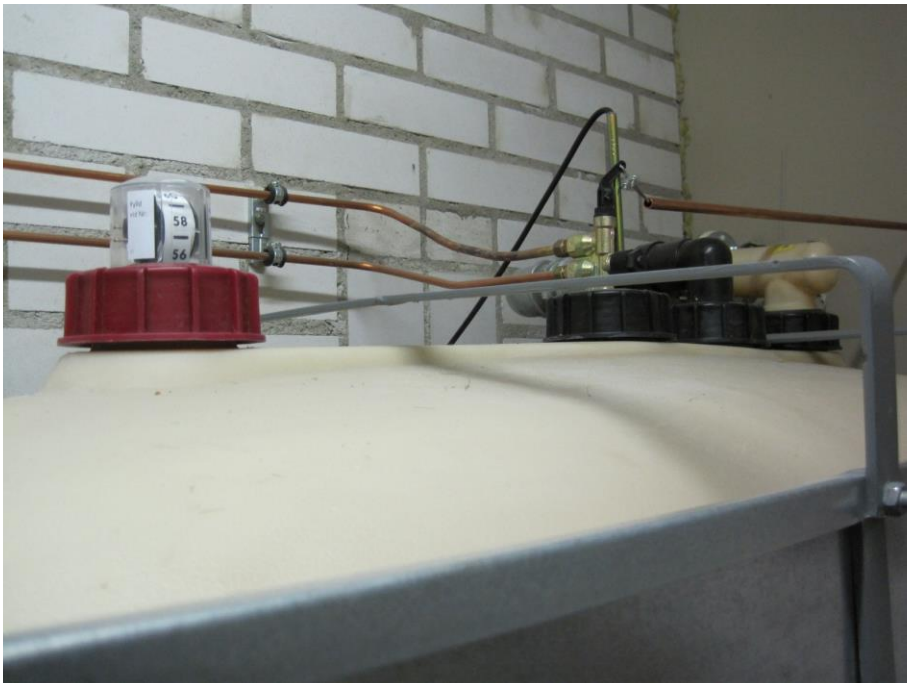

FIGURE 3. Plastic oil tank is located inside the building in a separate boiler room. (Photo: Tarja Asikainen.)

FIGURE 4. Metallic oil tank is located inside an underground bunker. (Photo: Tarja Asikainen.)

A technical useful life of an oil boiler is estimated to be 25 – 30 years and respectively concerning a metal tank about 30 years (Öljyalan Palvelukeskus Oy 2014a, Öljyalan Palvelukeskus Oy 2014b). Corrosion is a real risk, if the metal tank is in contact with water either from inside or outside, and, in the worst case, on both sides of the wall (Asikainen et.al 2014, 21). Corroded metal tanks have been repaired from inside by covering the wall with glass fibre or plastic, but the thickness of the wall is impossible to inspect after the covering. Note that the covering is nowadays forbidden in the city of Lahti and in the municipality of Hollola. Although welding is an accepted method, it is strongy recommended to renew the unsound or leaking oil tank instead of repairing it. (Päijät-Häme rescue department 2014b.)

Plastic tanks are estimated to have a longer technical useful life than metal ones, polyethylene (PE) tanks about 30 – 40 years and nylon (polyamide) tanks about 50 – 60 years. The pipelines and the joints between the pipes and the plastic tank should be inspected and rebuilt, if necessary. (Lipsanen 2015.) A technical useful life of fibreglass tanks was not available, but according to the manufacturer’s estimation, the fibreglass tank is long-lasting when they are properly installed (Kieksi 2015).

The risk of an oil leakage increases during the refuelling, if the joints are not tight or the seals have worn out. Plastic tanks have been installed since 1970s, mainly inside the buildings, but also a minor amount in the underground in the city of Lahti and in the municipality of Hollola (Heikkinen 2015). The oldest plastic tanks were installed nearly 40 years ago, which means that their renewal will be a topical issue in the near future.

The price of oil products has changed a lot during the last decade (Figure 5). The price increased until 2008 when it collapsed due to the global financial recession (Eurooppatiedotus 2012). Expecially the price of light fuel oil (heating oil) collapsed about 50 % during half a year in 2008. In less than four years, the price has increased to the highest level. Thereafter, the trend has been slightly downward. However, when looking at a long-term trend, the price of oil has constantly climbed up. A variety of geopolitical and economic events affect to the price of crude oil. (Finnish Petroleum and Biofuels Association 2015a; Statictics Finland 2015f.)

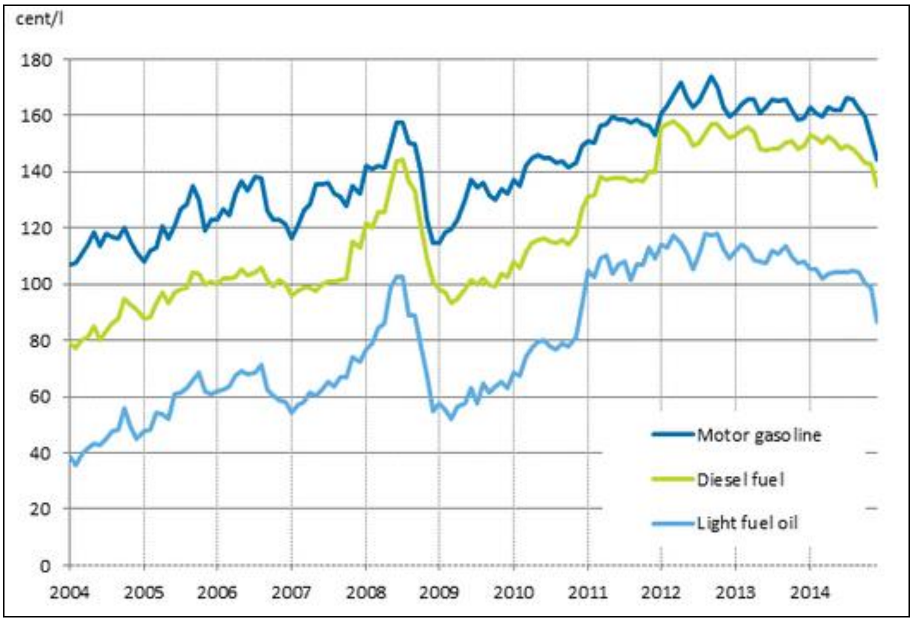

FIGURE 5. Consumer prices of principal oil products in 2004 – 2014: Motor gasoline, diesel fuel and lightfuel oil (heating fuel oil) (Statistics Finland 2015f).

GHG emissions are formed in the burning process of oil products. Since 2009, bio fuel has been added to heating oil to decrease the carbon dioxide (CO_2) emissions. The objective is to increase the share of bio fuels by 10 % by 2016. (Finnish Petroleum and Biofuels Association 2015b.)

3.1.2 Other methods of heat generation

Wood heating, district heating and electric heating have been the prevailing systems in replacing oil heating as recently as 2000s (Vihola & Heljo 2012, 42). New heating systems have been developed to replace oil heating. Hybrid solutions, which are connected with oil heating, have also become more popular.

Renewable energy sources that support sustainable development are geothermal heat, heat pumps as well as the hybrid heating systems consisting of solar thermal collectors. Also, a dual boiler is an alternative heating system, where separate furnaces are used for chopped firewood and heating fuel oil.

The Home Repairer publications of the Building Information Foundation RTS has studied the choices of the heating system repairers in 2006 – 2013 in Finland. Only private property owners were included in the surveys. The popularity of geothermal heat has been increasing (Figure 6). Support heating systems were also counted with the statistics. A very small share of the detached houses will be heated by oil at the end of 2028, based on the present rate of abandonment. The changes in the heating systems were reviewed regarding electricity, pellets, wood, district heating and geothermal heat. (Vihola et.al 2012, 42; the Building Information Foundation RTS 2013, 196.)

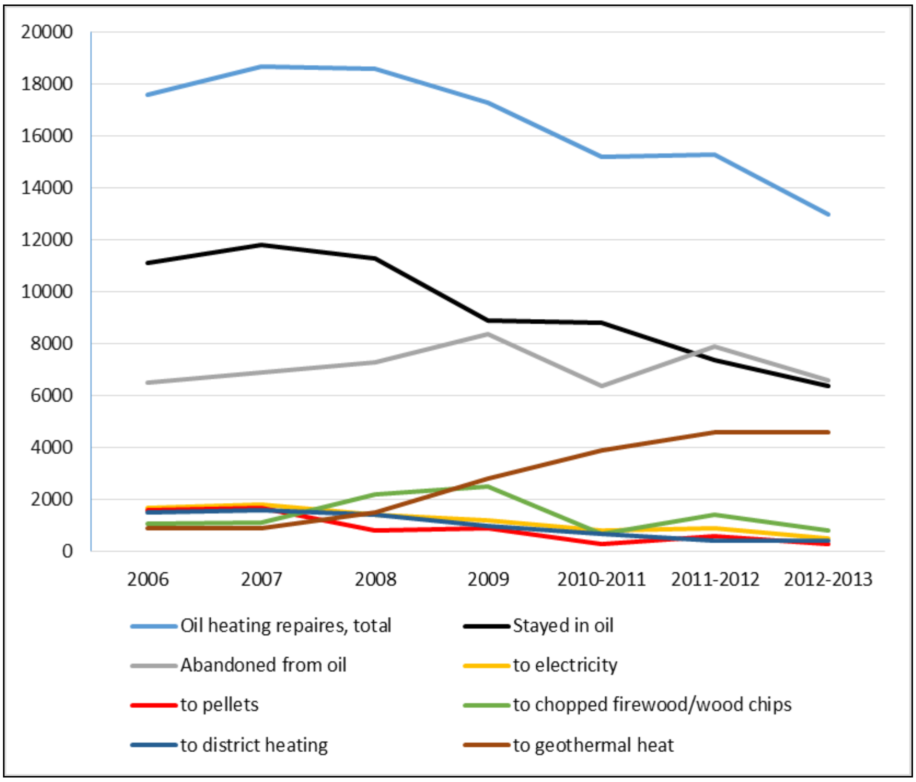

FIGURE 6. The amount of heating system repairers and changes in heating systems in Finnish small buildings in 2006 – 2013 (Vihola et.al 2012, the Building Information Foundation RTS 2013, 196).

3.2 Centralized heat generation

The operational principle of district heating is more simple than when using oil heating from the consumer’s point of view. Actually, heat is delivered as hot water to the properties in a closed district heating network consisting of two pipes, which are installed inside one insulated pipe (Figure 7). The temperature of hot water varies between 65 – 115 °C depending on the weather and the seasons. The temperature of water which is returned from the property to the plant varies between 40 – 60 °C. A heat distribution centre (Figure 8) is only needed without a separate hot water boiler, therefore the space requirement is similar to a cupboard in detached houses. District heating water is not circulated in the heating pipelines of the building. Water is dyed slightly green to detect a possible leakage in the district heating network, but the colorant is not a danger to the health or the environment. (Finnish Energy Industries 2015a.)

FIGURE 7. In the first phase, the district heating pipeline (diameter 180 mm) is installed in the building. In this case, the installation was done in the basement from where the oil tank and the oil boiler were removed. (Photo: Tarja Asikainen.)

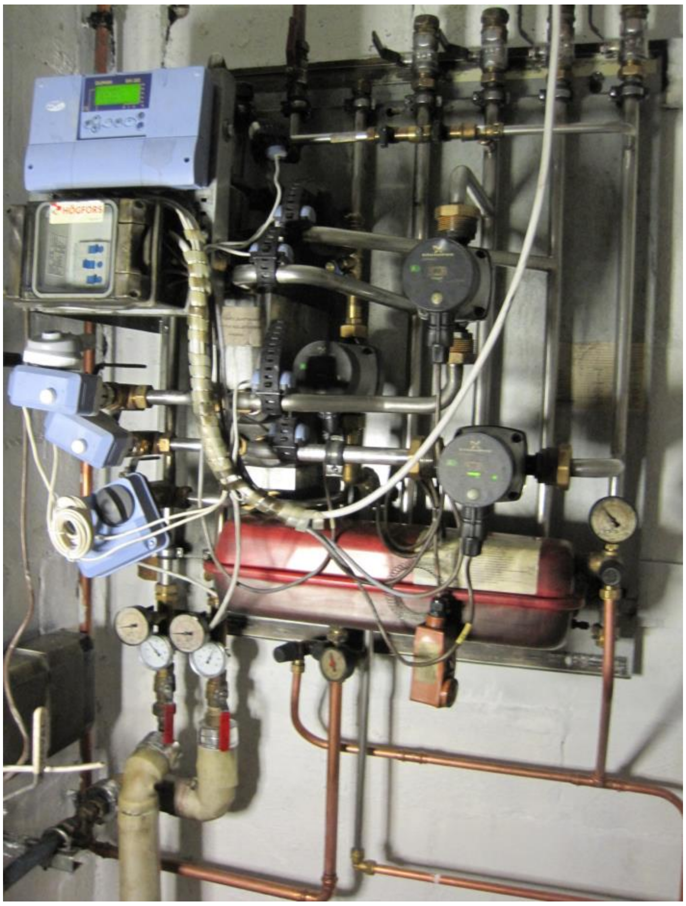

FIGURE 8. The heat distribution centre is installed in the technical room. Part of the pipelines are not visible in the photo. (Photo: Tarja Asikainen.)

The technical useful life of a heat distribution centre is estimated to be 20 – 25 years (Motiva Oy 2015b). A thorough review is recommended at the latest 15 years after the installation of the heat distribution centres. The functionality of the devices is inspected, as well as a possible need to renew the devices. The reviews are carried out by energy companies’ inspectors, heat contractors, equipment manufacturers and HVAC (heat, ventilation and air conditioning) engineers. Before starting the renewal process, the property owner is recommended to contact the heat deliverer. (Finnish Energy Industries 2007, 15.)

3.2.1 Heat energy generation in Lahti Energy Ltd

In this thesis, the cooperation partner is the local energy company Lahti Energy Ltd, whose main line of business is combined heat and power generation. The company owns four combined heat and power plants (CHP plants: Kymijärvi I, Kymijärvi II, Heinola and Teivaanmäki), twenty heating plants, and two gas turbine plants in the Lahti region. All installations, except the Kymijärvi II CHP plant belong to the EU Emissions trading system (EU ETS) (Energiavirasto 2015, Lahti Energia 2015b).

According to the environmental permit, the Kymijärvi II CHP plant (district heat capacity: 90 MW and electricity capacity: 50 MW) is classified as an installation of the incineration of municipal waste, and therefore Emission Trade Act is not applied (Päästökauppalaki 311/2011, Section 2; Ympäristöhallinto 2014; Wallin 2015c). The fuel mix consists of waste biofuels, such as wood chips, wood waste, energy waste from households and packing waste. Also, natural gas can be used as the additional fuel. (Ympäristöhallinto 2014.) The Heinola power plant produces only heat and electricity to the industrial sites nearby (Lahti Energia 2014b). A significant share of district heating was generated in the CHP plants, about 75 % in 2013 (Lahti Energia 2015a).

Both renewable and fossil fuels are used in heat and electricity generation in Lahti Energy Ltd. The share and the amounts of used fuels vary annually (Figure 9). The share of the renewable fuels increased in 2013 – 2014 compared to 2012 because heat and electrity generation starded in the new Kymijärvi II CHP plant. (Lahti Energia 2013, 12; Lahti Energia 2014a.)

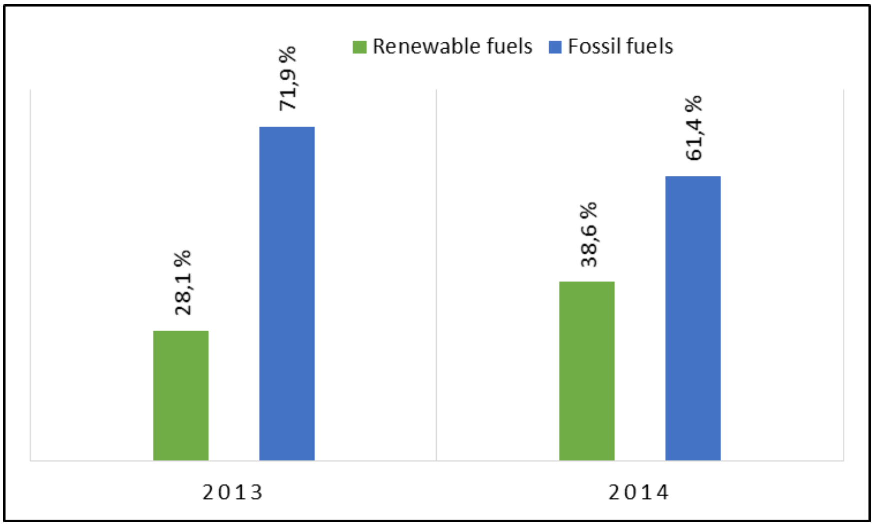

FIGURE 9. Share of renewable and fossil fuels in 2013 – 2014 in heat and electricity generation Lahti Energy Ltd (Lahti Energia 2014a, Lahti Energia 2015c).

In 2014, the distribution of the used fuels in heat and electricity generation is presented in Figure 10. Coal, natural gas and oil are classified as fossil fuels. Bio fuels and bio gas are classified as renewable fuels and recovered fuels as mixed fuels, where the default bio share is 60 % (Statistics Finland 2015c).

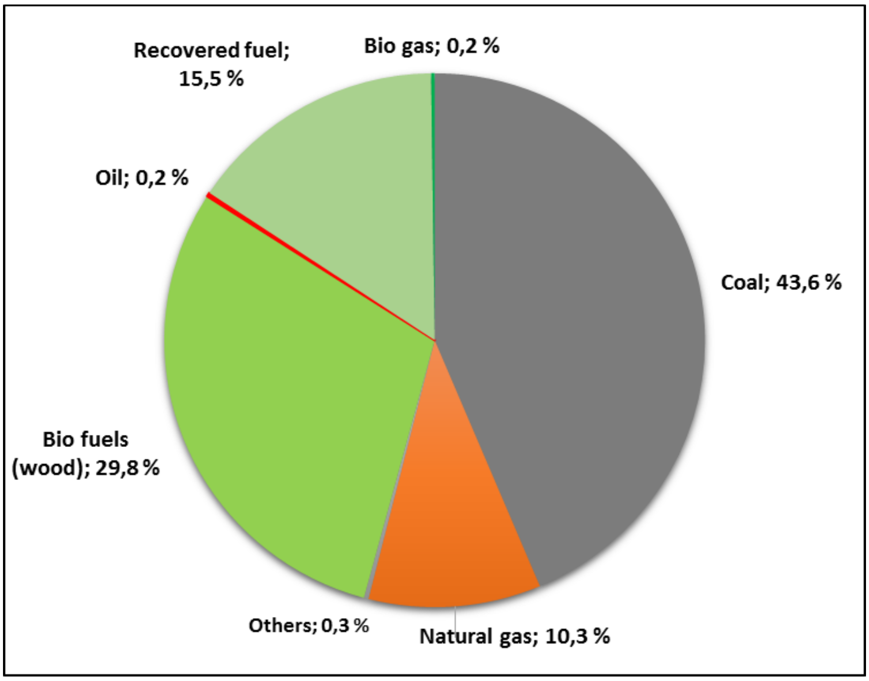

FIGURE 10. The distribution of used fuels in heat and electricity generation of Lahti Energy Ltd in 2014 (Lahti Energia 2015c).

The district heating network covers the densely populated areas of the municipalities of Hollola and Nastola which are connected by the main pipelines to the network of the city of Lahti. A separate network is built in the municipality of Asikkala. The total length of the district heating network is 660 kilometres. Maps of the networks in Lahti and in Hollola are presented in Appendices 3 and 4. The district heating network is marked on the map with red colour. Yellow and green pipelines are other pipelines. (Lahti Energia 2014b.) All installations, except the Heinola power plant and the Polttimo heating plant, are connected to the grid (Wallin 2015c).

The prices of district heat in households are presented in Figure 11, where the prices of Lahti Energy Ltd and the average prices in Finland are compared with each other in 2006 – 2015. District heat is measured in megawatt hours (MWh). Both prices include power and energy charges. Pricing is regulated by energy taxation, as well as emission trading influences to the price. The price also depends on the fuels used in heat generation. (Finnish Energy Industries 2015b.) Though the price of district heat has risen in the Lahti region, it remains below the average price in Finland. The price has increased 77 % in Lahti Energy Ltd and the average price in Finland 76 % in 2006 – 2015. In the same time period, the consumer price of heating oil has increased, but there has been a significant fluctuation in the price of oil (Finnish Petroleum and Biofuels Association 2015c).

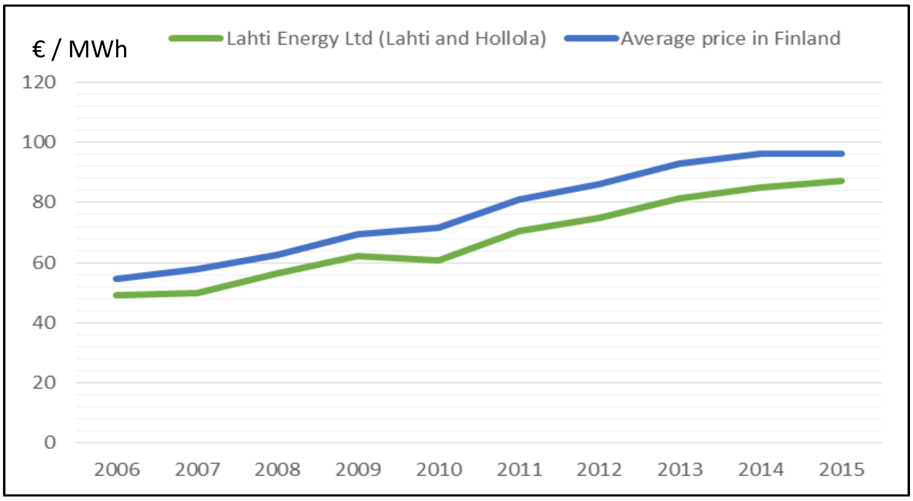

FIGURE 11. Consumer price of district heat in households in 2006 – 2015, € / MWh. Prices were checked on 1 January in 2006 – 2015 (Finnish Energy Industries 2015b).

3.2.2 Planning the new CHP plant Kymijärvi III in Lahti

Lahti Energy Ltd's owner, the city of Lahti, has set in their strategy the objective to be a comprehensive sustainable development city, and the forerunner in the climate change work. The target is to halve GHG emissions to 1990 levels by 2025 in the city of Lahti. It is clear that decisions concerning energy generation in the future help considerably to achieve the total target. Lahti Energy Ltd's own objective is to reduce carbon dioxide emissions in energy generation, as well as to minimize environmental risks in the operations. (Lahti Energia Oy 2013, 11.)

The first CHP plant, Kymijärvi I (district heat capacity: 190 MW and electricity capacity: 125 MW), was built in 1975 to the Kymijärvi region. The old plant does not meet the new EU's air protection regulations after 2015. Without considerable investments to reduce air emissions (sulphur dioxides, nitrogen oxides and solid particles) Kymijärvi I is allowed to still use 17 500 hours since 2016, after which the use of the plant must be stopped. Lahti Energy Ltd has drawn up a report, Environmental Impact Assess (later EIA), to replace Kymijärvi I with the new multifuel power plant to the Kymijärvi region (Figure 12). The project is called Bio2020. (Lahti Energia Oy 2013, 11 and 14.)

Kymijärvi III is needed to secure heat delivery to the district heating network and also to electricity generation. The total capacity is planned to be 310 MW. The technical useful life is estimated to be over 40 years. The starting point for the planning is that the fuel consists of biofuels 70 % and peat 30 %. The alternatives for fuel assortment are biofuels (0 – 70 %), coal (0 –100 %), peat (0 – 30 %) and recovered fuels (0 – 10 %). According to the EIA, Kymijärvi III will be built between 2016 – 2018, and the target for commercial use is set in 2019. Furthermore, terminal operations for the storage of biofuels are inspected. (Lahti Energia Oy 2013, 11-18 and 69.)

The environmental permit is currently in the application phase. According to Lillman, the objective is to take Kymijärvi III in use in 2021 (Lillman 2015.) The total capacity of Kymijärvi III will be reduced from planned (Wallin 2015c).

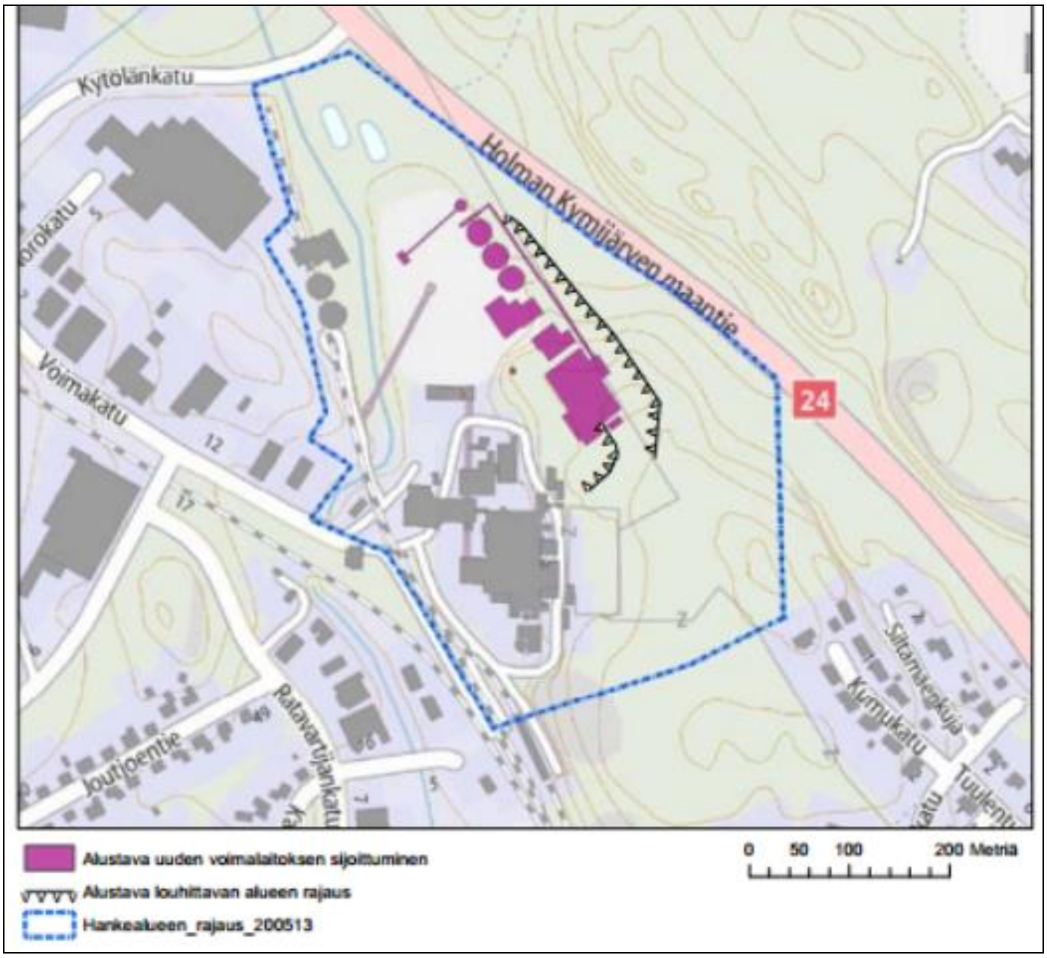

FIGURE 12. The location of the new multifuel power plant, Kymijärvi III, is presented with red/violet in the Kymijärvi region. The definition of Bio2020 is marked with a blue line. The Kymijärvi I and Kymijärvi II CHP plants are located between Voimakatu and Kymijärvi III (Lahti Energia Oy 2013, 14).

4 INTERVIEW SURVEY

This research is classified as qualitative research where a survey group was chosen appropriately (Hirsjärvi, Remes & Sajavaara 2009, 164). The research was implemented by interviewing a limited number of oil-fired property owners by telephone during spring 2014 and autumn 2014. In this thesis, all data contact details of the interviewees were handled anonymously and with confidentiality.

4.1 Selection of oil-fired properties

The most potential target group for interviews located in the district heating network area, where a low number of district heating customers exist. Practically, this means that the district heating network was built in old residential areas where the demand came up to renovate the existing heating systems. Detached house areas built in 1960s and in1970s were the most interesting for the interview survey because at that time oil heating was the prevailing heating system in new residential areas. (Wallin 2014a.) Oil-fired heating systems, built in 1960s and 1970s, are estimated to be at the end of the useful life.

The residential areas for the interviews were selected together with the heat business department of Lahti Energy Ltd. The preliminary meeting was carried out in March 2014, when the main discussion topics were the target of the research and the research plan. After accepting the topic of the thesis, the cooperation agreement and the non-disclosure agreement were signed in March 2014.

The register of the oil tanks (known as Merlot) is maintained by the Päijät-Häme rescue department within the region of Päijät-Häme. The cooperation with the Päijät-Häme rescue department and the TANKKI project, of which the researcher of this study was in charge, enabled to use Merlot as the source data. Merlot includes information concerning oil-fired properties, such as addresses and detailed data of the oil tank: installation year, latest inspection date, classification and location (Heikkinen 2014).

The names of the property owners are available in Merlot, but not in a printed list of the oil tanks. As the method to find out the property owners for the interviews a comparison of two databases was used, Merlot and the district heating network. Merlot includes separate databases for the oil tanks that are in use and for decommissioned oil tanks. Only tanks in use were included in this survey. Because the interviews were done by calling, the task was to find out potential properties, the names of the property owners and their telephone numbers.

Oil-fired property owners were selected to the interviews as follows:

- Addresses of oil-fired properties were searched from Merlot, maintained by the Päijät-Häme rescue department (not publicly available).

- The district heating network database, Fiksu Verkosto Info, was used as an online connection (confidential database maintained by Lahti Energy Ltd).

- Potential oil-fired properties were found out by comparing the Merlot and Fiksu Verkosto Info databases.

- The names of oil-fired property owners were found from the TANKKI oil tank study and partially from the customer register of Lahti Energy Ltd (Wallin 2014c). Large oil tank study was implemented in the municipality of Hollola in 2013 during the TANKKI project and many oil tank owners participated in the study.

- Limitations: Only those oil-fired properties were selected, which located next to a district heating network and the telephone numbers of the property owners were found on the internet. Part of the telephone numbers were found from the customer register of Lahti Energy Ltd (Wallin 2014c, Wallin 2014d).

Because the district heating network covers large areas in the Lahti region, many potential residential areas were estimated to be applicable to the survey. According to the researcher's proposal, the survey was started from the municipality of Hollola. At this stage, it was agreed that the researcher interviews the selected residential areas in Hollola. Lahti Energy Ltd expressed its interest to expand the survey to cover some older areas of the city of Lahti. The decision was not made concerning the expansion in March 2014, because the extent of the survey was not anticipated in advance. All potential oil-fired properties were included to the survey because it was impossible to predict how many of them would be willing to participate in the survey. After finishing the interviews in the Hollola region, the extension of the survey was analysed by the researcher. Although the interviews were implemented with a good response in Hollola, it was interesting to carry out the second survey in the city of Lahti to find out possible differencies between the two municipalities.

4.2 Survey questions

The questionnaire was planned together with Lahti Energy Ltd (Wallin 2014b). The survey included altogether 16 open questions concerning an oil tank, an oil boiler, oil consumption and district heating. One question handled the environmental aspects of district heating. At the beginning of the interview, it was verified that the interviewee owns the property. The original questionnaire was in Finnish (Appendix 5).

<u>Survey questions were as follows:</u>

1. Interviewee and age (classes: under 30 years, 30 – 50 years, over 50 years)
2. Address and the type of the building

Questions concerning the oil tank:

3. Capacity
4. Location
5. Material
6. Classification (according to the legislation)
7. Latest inspection year
8. Installation year; age of the oil tank

Questions concerning the oil boiler and oil consumption:

9. Age and the condition of the oil boiler

10. Annual oil consumption

Questions concerning district heating:

11. Has the energy company offered district heating in the recent years?

12. Have you now considered joining district heating? Yes / No, reason:

13. What is your attitude concerning district heating as a heating system?

14. What is your understanding concerning the economy of district heating?

15. What is your understanding concerning the magnitude of the investment costs and the cost-effectiveness of district heating?

16. What is your understanding concerning the eco-friendliness of district heating compared with oil heating?

4.3 Telephone interviews

The research was implemented by interviewing a limited number of oil-fired property owners by a telephone survey. The first target group was located in three old residential areas of the municipality of Hollola. The second target group was located in two old residential areas of the city of Lahti.

The telephone interviews were implemented in two phases, in May – June 2014 and in September 2014. The calls were conducted from Monday to Thursday at 6 – 8 p.m. The duration of one call was about 10 – 25 minutes, depending on the content of the interviewees' answers and knowledge of the heating system. Many of the older interviewees answered more detailed and widely than required. An interview with open questions is challenging from the point of the researcher expecially in the cases when the issue is getting out of hand.

All answers were written into the questionnaires during the interviews (not recorded). At the beginning, the interviewees were asked to give permission to deliver detailed answers with the contact information to Lahti Energy Ltd. Only one interviewee forbade to deliver his/hers contact information forward.

5 RESULTS

5.1 Summary of the interviews

Altogether 61 oil-fired property owners were interviewed during May 2014 – September 2014. The summary of the interviews is presented in Table 3. The total response rate was 79 %, which was higher than it was predicted by the researcher. People have negative attitudes to telephone interviews, so the result can be valued. One reason for the high response rate may be that the interview topic deviated from a typical gallup and an economy research. Only six oil-fired property owners were not interested in participating in the survey. Also, ten oil-fired property owners could not be reached within three to four calls.

People were easier to reach in September after the holiday season. The best time for the calls were rainy evenings, when many of the interviewees were reached during the first call.

TABLE 3. Summary of the telephone interviews and the response rate during May 2014 – September 2014.

	Hollola	Lahti	Total
Duration of interviews:	May – June 2014	September 2014	
Summary of the interview:	23 June 2014	1 October 2014	
Target group:	41	36	77
Interviewed:	32	29	61
Not reached:	5	5	10
Not interested to answer:	4	2	6
Response rate:	78 %	81 %	79 %

The initial answers were written into the questionnaires. Raw data was transcribed to excel tables separately concerning the survey areas of Lahti and Hollola. In this thesis, the complete survey data is not presented for confidentiality reasons, but the example of survey data is presented in Appendix 6.

5.2 Classification of the survey

Survey data was combined for sorting and analysing data in excel. The classification of the answers concerning questions 4 – 8 was based on the legislation, other answers were classified from the point of the researcher’s own interest and knowledge. Some answers were also analysed separately in respect of Hollola and Lahti to find out possible differences between the municipalities. The answers were sorted as follows:

1. Gender of the interviewee and age:

Female	31 %
Male	69 %

Age:

Under 30 years	0 %
30 – 50 years	26 %
Over 50 years	72 %

The age of the property manager in the terraced house was not inquired.

2. Address and the type of the building:

Detached houses	59
Terraced house	1
Industrial building	1

Background questions (3. – 8.) concerning the oil tank:

3. Capacity (volume):

Under 2 000 litres	10 %
2 000 – 3 000 litres *	70 %
4 000 – 5 000 litres	13 %
10 000 litres (terraced house)	2 %
N/a	5 %

* 3000 litres is maximum volume which is allowed to store inside the boiler room.

4. Location:

	All	Lahti	Hollola
Inside the underground bunker*	59 %	55 %	63 %
Inside the building	41 %	45 %	37 %

* Bunker made of concrete

5. Material:

	All	Lahti	Hollola
Plastic	23 %	24 %	22 %
Metal	62 %	55 %	69 %
Metal (coated *)	11 %	14 %	9 %
N/a	3 %	7 %	0 %

* Corroded metal tanks have been coated from inside with plastic or fibreglass.

6. Classification according to the legislation:

	All	Lahti	Hollola
A	33 %	28 %	38 %
B	5 %	0 %	9 %
C	0 %	0 %	0 %
D	0 %	0 %	0 %
N/a (inspected) E.	44 %	52 %	38 %
Not inspected F.	10 %	10 %	9 %
Not relevant G.	8 %	10 %	6 %

A. Oil tank is in good condition.

B. Minor corrosion detected in metal.

C. Deep corrosion detected in metal.

D. Punctures detected in metal or plastic broken.

E. Classification was not remembered (not available).

F. Classification was not done.

G. New tank, which has been used less than 10 years.

7. Latest inspection year:

	All	Lahti	Hollola
Under 10 years ago a)	72 %	62 %	81 %
Over 10 years ago b)	3 %	7 %	0 %
Not inspected b)	10 %	10 %	10 %
Not relevant c)	8 %	10 %	6 %
N/a	7 %	11 %	3 %

a) Oil tanks have been inspected according to the regulations.

b) Oil tanks should have been inspected.

c) No need to inspect because oil tanks are new (less than 10 years in use).

8. Installation year, whereby the age of the oil tank was calculated from:

	Age of the oil tank	All	Lahti	Hollola
Under 1974	Over 40 years a)	38 %	52 %	25 %
1974 – 1984	30 – 40 years b)	39 %	17 %	60 %
1985 – 1994	20 – 29 years	0 %	0 %	0 %
1995 – 2004	10 – 19 years c)	10 %	14 %	6 %
2005 or later	Under 10 years c)	8 %	10 %	6 %
Not known	Renovated c)	3 %	3 %	3 %
N/a		2 %	4 %	0 %

Oil heating causes a risk for soil and groundwater pollution, therefore periodic inspections of oil tanks play a significant role. Legal and other requirements of oil heating were presented in section 2.2.1. Questions 4 – 8 were analysed together from the perspective of the oil accidents to find out amount of oil tanks that cause a risk for soil and groundwater.

a) Altogether 23 (38 %) over 40 year old oil tanks:

- All oil tanks were made from metal, of which five tanks were covered.
- Only eight metal tanks were located inside the building.

- The risk of an oil accident increases significantly if the classification is unknown or worse than A and/or the inspections were not carried out as required: 15 metal tanks cause a risk for the property owners.

b) Altogether 24 (39 %) oil tanks, whose ages were between 30 – 40 years:

- 22 oil tanks were made from metal, of which two were covered.
- Most of the metal tanks were located in the underground bunker, only three metal tanks were located inside the building.
- Two plastic tanks were located inside the building.
- The risk of an oil accident increases significantly if the classification is unknown or worse than A and/or the inspections were not carried out as required: 12 metal tanks cause a risk for the property owners.

c) Altogether 13 (21 %) oil tanks, whose ages were under 20 years:

- Most of the oil tanks were made from plastic. No information was available concerning the material of one tank.
- Most of the plastic tanks were located inside the building, only one was located in the underground bunker.
- The risk of an oil accident increases if the plastic tanks are not inspected as required: six oil tanks (age between 10 – 19 years) have never been inspected, which cause a risk for the property owners.

In conlusion, altogether 33 oil tanks cause the risk of an oil accident because the classifications were unknown and/or the inspections were not carried out in accordance with the regulations.

Background questions (9. – 10.) concerning the oil boiler and oil consumption:

9. Age and the condition of the oil boiler:

	All	Lahti	Hollola
30 years or older a)	28 %	21 %	34 %
Under 30 years b)	70 %	76 %	66 %
N/a	2 %	3 %	0 %

a) The oil boilers were original, and therefore they should be renewed in the near future to improve energy efficiency.

b) All expect one were renovated.

10. Annual oil consumption (in litres):

2 000 or under	56 %
2 000 – 3 000	30 %
3 000 – 10 000 a)	3 %
Over 10 000 b)	2 %
N/a	10 %

a) Two respondents: one detached house and one industrial site

b) One terraced house

Questions (11.-16.) concerning district heating:

11. Has the energy company offered district heating in the recent years?

Yes	74 %
No	16 %
N/a (1 terraced house)	2 %
No *	8 %

* Offers were asked by the property owners. At that time, the district heating network was not built to the residential area.

12. Have you now considered joining district heating? Yes / No, reasons:

	All	Lahti	Hollola
Yes	8 %	7 %	9 %
No	92 %	93 %	91 %

Yes, reasons: No equal answers.

No, reasons (number of answers):

- Expensive investment, long repayment period (14)
- The boiler or the oil tank has been renovated (19). Both equipment were renovated (10)
- Interested in the water-air heat pump (1)
- Oil heating is functioning (3). Note that equipment was original in these properties (ages between 35 – 47 years)
- Satisfied with oil heating (2)
- Not interested in investments (1)
- Because of the cost/economic reasons (2)
- The building is in the minimal use (1)
- Not mentioned (3)

13. What is your attitude concerning district heating as a heating system?

	All	Lahti	Hollola
Positive attitude a)	72 %	79 %	65 %
Negative attitude b)	10 %	7 %	13 %
Neutral attitude c)	18 %	14 %	22 %

a) Reasons: Easy care, painless, carefree, safe, reliable, stable, good, excellent

b) Reasons: Dominant market position (term “monopoly” was used in the answers).

c) No understanding or no answer

14. What is your understanding concerning the economy of district heating?

	All	Lahti	Hollola
Less expensive than oil heating	25 %	21 %	28 %
More expensive than oil heating	18 %	21 %	15 %
Same price	11 %	14 %	9 %
Price increased (recently)	15 %	10 %	19 %
Dominant market position *	8 %	3 %	13 %
No understanding (or not best choice)	23 %	31 %	16 %

* There is no ability to influence the price of energy after choosing district heating.

15. What is your understanding concerning the magnitude of the investment costs and the cost-effectiveness of district heating?

Investment in euros	All	Lahti	Hollola
Under 8 000	18 %	14 %	22 %
8 000 – 10 000 *	31 %	28 %	34 %
10 000 – 20 000	15 %	17 %	13 %
Over 20 000	2 %	0 %	3 %
No understanding	32 %	38 %	28 %
Same price as new boiler investment	2 %	3 %	0 %

* Lahti Energy Ltd’s offer for detached houses was 8 300 euros which was the minimum fixed price for district heating in 2014.

Cost-effectiveness: No answers.

16. What is your understanding concerning the eco-friendliness of district heating compared with oil heating?

	All	Lahti	Hollola
More environmentally friendy a)	59 %	62 %	56 %
Less environmentally friendly b)	16 %	14 %	19 %
No difference	7 %	7%	6 %
No answer (no understanding)	18 %	17 %	19 %

a) Reasons: Air emissions are reduced in residential areas. Also, combustion gases are purified better in the power plant than in private houses. Only one mentioned that oil heating causes a risk for soil pollution.

b) Reasons: Coal and waste are used as the fuels in the power plants.

5.3 Analysis of the municipality-specific answers

The answers of questions 4 – 9 and 12 – 16 were analysed separately. Following differencies were observed in the survey areas in the city of Lahti and the municipality of Hollola:

- Q4 / Location: Difference concerning the location of the oil tanks was minor in Lahti as in Hollola. Significant portion of the oil tanks were located inside the underground bunker in Hollola.
- Q5 / Material: The metal tanks were found out a little bit more in Hollola.
- Q6 / Classification of the oil tanks: The oil tanks were inspected but the classification was not remembered in 52 % of the responses in Lahti, while in Hollola the result was 38 %. B –class tanks were only found out from Hollola. One reason, that only A –class tanks were reported to be in Lahti, might be that the classification was not available in 52 % of the responses.
- Q7 / Inspections: The inspections of the oil tanks were implemented more frequently in Hollola, instead the same number of the property owners in both municipalities have not taken care of the obligatory inspections.
- Q8 / Age of the oil tanks: Over 40 year old tanks were located significantly more in Lahti, instead 30 – 40 year old tanks were located significantly more in Hollola. Oil tanks were renewed more in Lahti.
- Q9/ Age of the oil boilers: The oil boilers were renovated a little bit more in Lahti.
- Q12 / Interest in district heating: No noticeable differency.
- Q13 / Attitude to district heating: Positive attitude was found out in 79 % of the responses in Lahti, while in Hollola the result was 65 %.

- Q14 / Economy: District heating was estimated to be less expensive than oil heating in more answers in Hollola, while more respondents in Lahti estimated district heating to be more expensive. Dominant market position was emphasized more in Hollola. Also, the answer “no understanding” emphasized in Lahti.

- Q15 / Investment costs: The most realistic estimations were found out in Hollola. The answer “no understanding” was high (32 %) in total, but the number of the answers were a little bit higher in Lahti.

- Q16 / Eco-friendliness of district heating compared with oil heating: District heating was estimated to be more environmentally friendly alternative in more answers in the survey areas of Lahti than in Hollola. The use of coal came up in all answers (except one) where district heating was estimated to be less environmentally friendly. No significant differency was found out between other answers.

In conclusion, concerning questions 4 – 9, a significant deviation was only observed regarding the ages of the oil tanks. According to the answers, over 40 year old, original oil tanks were plenty in use in the survey areas of Lahti. However, most of the oil boilers were renewed in these properties. Instead, in the survey areas of Hollola, most of the oil tanks were 30 – 40 years old.

In conlusion, concerning questions 12 – 16, the attitude for district heating was a little bit more positive in the survey areas of Lahti. Furthermore, the most realistic estimations regarding the investment costs of district heating were found out in Hollola.

Because the significant differences were only observed a little in this municipality-specific analysis, the economical and environmental aspects are next reviewed with relation to the entire survey data.

6 ECONOMICAL AND ENVIRONMENTAL ASPECTS

6.1 Analysis of the respondents' interests

In this thesis, comparative calculations between district heating and oil heating were drawn up to find out the actual investmest and annual costs. Economy and people's attitudes affect the acquisition of a heating system. Question 11 was asked to get information concerning earlier contacts with the energy company: 74 % of the respondents had received an offer to join district heating. Offers were also asked by a few property owners. Questions 12 –14 were posed to find out the interests, attitudes and understandings of the oil-fired property owners between oil heating and district heating.

Question 12 handled the respondents' consideration to join district heating. All oil-fired properties were located in the streets, where a district heating network exists. At the moment 8 % of the oil-fired property owners were interested in district heating, but for different reasons. When looking at the answers of the interested respondents, both new and old (over 30 years) oil boilers were in use in the properties. Instead, all oil tanks were old (36 – 42 years) and located inside an underground bunker. In practice, the renewal of the oil heating system is extremely timely. Most of the oil-fired property owners (92 %) had not considered to join district heating. Major reasons for the lack of interest were the fact that the oil-fired heating system had been renewed (16 %), as well as district heating was estimated to be an expensive investment, and a long repayment period.

Question 13 handled the respondents' attitudes concerning district heating as a heating system. Positive attitude came up in 72 % of the responses. District heating was considered to be a carefree, safe, reliable and stable heating system. Dominant market position was mentioned in a few answers. Also, 18 % of the respondents had not thought about the issue. When looking at the answers of the age group of 30 – 50 years, all respondents had a positive attitude to district heating.

Question 14 handled the respondents' understanding concerning the economy of district heating. As many as 25 % of the respondents estimated district heating to be less expensive than oil heating. 11 % of the respondents supposed that heating costs are at the same level. Only 18 % of the respondents considered oil heating to be less costly, which was an unexpected result. The most interesting group was the respondents (23 %, 14 respondents), who had no understanding concerning the economy of district heating. According to their answers seven respondents had renewed oil boilers but oil tanks were not renewed at the same time. In these properties the oil tanks were made from steel and were installed during years 1964 –1974, i. e. the oil tanks were 40 – 50 years old. In reality, the oil tanks should have been renewed. Furthermore, two respondents had original oil boilers and oil tanks in use, which were installed 35 and 47 years ago. Although all these nine oil tanks were inspected within 12 years, they still cause a risk for the environment, and also for the property.

Noteworthy is that none of the respondents mentioned the fluctuation of oil price. However, the price of heating fuel oil increased from 2009 until 2012, thereafter the price turned to a slight decrease (Figure 5). Whereas 15 % of the respondents said that the price of district heating had increased recently.

6.2 Investment costs

Question 15 was asked to find out about oil-fired property owners’ understanding concerning the investment costs of district heating. 31 % of the respondents estimated the investment costs to be 8 000 – 10 000 euros and 18 % of the respondents under 8 000 euros. 32 % of the respondents (20 oil-fired property owners) had no understanding regarding the investments costs. When looking at their answers, only one of them was interested in district heating. Even nine respondents had over 40 year old oil tanks, but six of them had renovated the oil boiler which might explain their lack to know the investment costs.

It can be predicted that old oil tank owners have to invest in the heating system in the near future either by renewing at least the oil tank, or by renewing the oil tank and the oil boiler, or changing to another heating system. When planning an investment, it is necessary to consider available heating systems that are technically applicable to the property.

In this study, only the investment costs of changing from oil heating to district heating were examined, as well as renewing oil heating. Accurate investment costs are not available in the literature concerning oil heating. Investment costs strongly depend on the size of a new oil boiler and an oil tank, the size of a boiler room, as well as the location of an oil tank. The contractor’s estimation for the investment is 10 000 – 15 000 euros, which includes an oil boiler, an oil burner, a plastic oil tank, pipelines and all installation costs (Tiihonen 2015). A new oil heating system to a detached house was estimated to pay 7 840 euros in 2010 (Havulehto 2010, 65).

The investment costs of district heating are accurate if the property is located near the district heating network. At the moment Lahti Energy Ltd provides district heating with a fixed price, 8 300 euros, for detached houses. The price includes 20 metres pipelines outside and 2 metres pipelines inside the building. (Wallin 2015a.) In all renovation cases the old oil tank must be cleaned up, which causes costs about 400 euros. In most cases, it is necessary to demolish partially or totally the old heating system which causes extra costs about 1 000 euros. (Mäki-Korvela 2015.)

6.3 Annual costs

In addition to the investment costs, it is necessary to review the annual operating costs. The calculations, presented in this thesis, are the theoretical and approximate examples, and therefore they cannot be used directly for the purposes of an investment plan. The calculations are applied to the detached houses supplied with an old oil boiler of 72 % efficiency (Motiva Oy 2015c).

The annual costs were defined for two typical oil consumptions of the detached houses: 2 000 and 3 000 litres per year. The annual energy use (in MWh) was used to find out the annual costs of district heating if the same energy use should be generated with district heat instead of oil heating. The calculations are presented in Appendices 7 – 10 and summarized in Table 4. The prices of the fuels are tied to the interview moment in 2014 and to the reference date in February 2015. The purpose was to find out impacts to the annual costs that are caused from the fluctuations of oil price. (Finnish Energy Industries 2015b, Finnish Petroleum and Biofuels Assosiation 2015c).

The maintenance costs are included in the annual costs of oil heating, about 240 euros per year. It includes an oil burner service, sweepings of a flue, and an oil boiler. (Suontama 2015, Tiihonen 2015.) The annual inspection costs of an oil tank are not included because the frequency of the inspections affects to the costs.

According to this study, the annual costs of district heating were estimated to be lower in each calculation examples (Table 4, cases 1 – 4). The savings were lower in cases 1 and 2, where oil consumption was 2 000 litres per year. The saving seems to be higher when oil consumption is highier. Practically, this means that a repayment period of an investment is shorter if oil consumption is higher. The repayment periods and case 7 are handled more in the section 6.4.

TABLE 4. The annual costs of oil heating and district heating calculated with different oil consumptions at the interview moment in 2014 and the reference date in February 2015 (Energiatehokas koti 2012, Finnish Energy Industries 2015b, Finnish Petroleum and Biofuels Assosiation 2015c, Motiva Oy 2015c, Suontama 2015, Tiihonen 2015).

			Prices		Annual costs, €		
	Oil consumption in litres	Energy use in MWh	Oil € / litre	DH € / MWh	OH	DH	Annual saving
May-Sep 2014, case 1	2000	14.53 *	1.04	85.19	2320	1238	1082
Feb 2015, case 2	2000	14.53 *	0.93	87.16	2100	1267	833
May-Sep 2014, case 3	3000	21.80 *	1.04	85.19	3360	1857	1503
Feb 2015, case 4	3000	21.80 *	0.93	87.16	3030	1900	1130
Feb 2015, case 5	2000	14.53 *	0.51	87.16	1260	1267	-7
Feb 2015, case 6	3000	21.80 *	0.55	87.16	1893	1900	-7
Feb 2015, case 7	2350	21.80 **	0.93	87.16	2426	1902	524

OH means oil heating.
DH means district heating.
* Energy use in MWh was calculated by using efficiency 72 %, which is a typical efficiency for an old oil boiler.
** Energy use in MWh was calculated by using an average efficiency 92 % which is a typical efficiency for a new oil boiler.

As many as 11 % of the respondents estimated that there is no difference in the annual costs between oil heating and district heating (question 14). The same calculation method as used in cases 1 – 4 can also be used to assess different situations by changing one or more parameters. For example, in order that the annual costs would be at the same level in both heating systems in 2015, the price of oil should be about 0.5 € per litre (Table 4, cases 5 and 6). The calculations are presented in Appendices 11 and 12. Even if the price of oil fluctuates, it is unlikely that the price will remain at the low level (0.5 € per litre) permanently. The long-term price trend is seen in Figure 5 where the slope is positive.

The periodic pricing is in use in Lahti Energy Ltd, and therefore the Finnish Energy Industries has calculated the energy price which represents the annual costs for the different types of houses (Finnish Energy Industries 2015b).

6.4 Repayment periods

The repayment period of an investment is one of the most significant issues before the decision-making. For example, the saving which consists of changing from oil heating to district heating is calculated in case 4 (Table 4). The investment costs are devided with the annual saving: 8 300 € / 1 130 € = 7.4 years, which is the estimated repayment period concerning case 4. If oil consumption is lower as in case 2, the estimated repayment period is longer. The repayment period was calculated by assuming the price of oil is stable, but in reality the fluctuation of oil price impacts to the repayment period.

In comparison, after renewing the oil boiler the annual saving was estimated in case 7, where case 4 was used as input data. The calculation is presented in Appendix 13. Because the efficiency of a new oil boiler increases, oil consumption was determined by using the approach “trial and error”. The value

92 % was used as an average efficiency of a new oil boiler (Energiatehokas koti 2012). Oil consumption was calculated backwards by utilizing the known annual energy use.

The annual saving between cases 4 and 7 was 604 euros per year. The repayment period was calculated by deviding the investment costs with the annual saving: 10 000 € / 604 € = 16.5 years. In reality, the investment costs, the fluctuations of oil price, and the efficiency of an oil boiler impact strongly to the repayment period.

Motiva has developed the calculator for comparing the investment costs and the annual costs of the heating systems. The calculator is designed for a consumer advisement. It can be used for new and old, and also different kind of single-family houses. The result of the calculation is an approximate. (Motiva Oy 2015c.) By using the same input data as in case 4 (Table 4) in the Motiva's calculator, district heating will be cheaper heating system than oil heating. According to the calculator, the annual saving is about 800 euros per year, respectively according to case 4, about 1 100 euros per year. In this context, the repayment periods were not inspected by the Motiva's calculator.

6.5 Greenhouse gas emissions

In this thesis, only carbon dioxide emissions (later CO_2 emissions) were included in the study. CO_2 is classified as a greenhouse gas which is released mainly from burning fossil fuels causing harmful changes in the climate. A long term goal is a carbon neutral society by 2050 which can be reached by enhancing the use of renewable energy and by raising energy efficiency (Ministry of Employment and the Economy 2013, Sections 7-11).

Question 16 was asked to find out oil-fired property owners' understanding concerning the environmental aspects of district heating compared with oil heating. 59 % of the respondents were under the impression that district heating is a more environmentally friendly heating system due to a better air quality in the residential areas, and also due to a better purification of the exhaust gases in the power plants. 25 % of the respondents felt no difference or had no understanding.

16 % of the respondents felt district heating to be less environmentally friendly due to coal and waste which are used as the fuels in the power plants.

The annual CO_2 emissions were calculated to find out the differences between oil heating and district heating. The calculations, presented in this thesis, are applied to the detached houses with an origin oil heating system where the efficiency of an old oil boiler is low (72 %). Furthermore, the annual CO_2 emissions of the whole research area were studied by estimating annual oil consumption in each property and by using an average efficiency of all oil boilers in the survey areas of Lahti and Hollola. The annual oil consumptions, reported by 89 % of the respondents, were combined. The annual CO_2 emissions of the whole survey area is presented in Appendix 14.

According to the calculations, presented in this thesis (Appendices 7, 9 and 14), CO_2 emissions of district heat generation were significantly minor if the energy use (in MWh) in households should be generated with district heat instead of oil heating with the existing oil boilers (Table 5.) The amount of CO_2 emissions is directly proportional to the use of fossil fuels in heat generation.

TABLE 5. The annual CO_2 emissions of oil heating calculated with different oil consumptions in 2014; and in the situation, where energy use is generated with district heat instead of oil heating (Commission Regulation (EU) No 601/2012, article 24:1; Motiva Oy 2015c; Statistics Finland 2015c; Wallin 2015b).

	Oil consumption in litres	Efficiency of oil boiler	Energy use in MWh	Annual CO_2 emissions of		Difference between emissions of OH and DH
				OH, tCO_2	DH, tCO_2	
Detached house	2000	72 %	14.53	5.3	2.8	47 %
Detached house	3000	72 %	21.80	8.0	4.1	49 %
Whole survey area	120000	80 %	968.93	321.0	183.9	43 %

OH means oil heating.
DH means district heating.

CO_2 emissions will decrease significantly in district heat generation in the Lahti region after 2021 when the multifuel power plant, Kymijärvi III, will be taken in use. The fuels of Kymijärvi III mainly consists of the renewable energy sources which also promote a long-term goal towards sustainable development.

CO_2 emissions, originated from burning heating oil, were calculated by using the calculation-based methodology and the fuel classification which are applied in the emission trading reports in Finland (Commission Regulation (EU) No 601/2012, article 24:1; Statistics Finland 2015c).

CO_2 emissions, originated from district heat generation of Lahti Energy Ltd, were determined by using the specific emission factor due to the composition of the used fuels in the power plants (Wallin 2015b). The CO_2 emission calculations are presented in Appendices 7 – 10.

7 CONCLUSIONS AND FINAL DISCUSSION

In this thesis, the opportunities of changing from oil heating to district heating in two residential areas in the city of Lahti and in three residential areas in the municipality of Hollola were studied. The studied residential areas were chosen in cooperation with Lahti Energy Ltd, which was the cooperation partner in this thesis. The survey was conducted by telephone interviews with the response rate of 79 %. Altogether 61 oil-fired property owners, who lived next to a district heating network, were interviewed during May 2014 – September 2014. The properties located in the survey areas were built mainly in 1960s and 1970s, and therefore original heating systems were estimated to be at the end of the useful life.

This research was a case study, and therefore the calculations concerning investment and annual costs can only be applied in the Lahti region. The calculations are useful estimations when comparing the heating systems. Furthermore, the survey questions 11 – 16 handled the oil-fired property owners' interests, understandings and attidutes concerning district heating. The results of these questions are not generalized.

Oil heating is still widely used in Finland, also in the Lahti region. The first research question handled this issue. According to the Home Repairer's studies in 2006 – 2013, the abandonment of oil heating in small private ownship buildings remained relatively at the same level each year. A very small share of detached houses will be heated by oil at the end of 2028, based on the present rate of the abandonment of oil heating.

According to this study, only 16 % of the oil-fired heating systems were renewed totally in the survey areas in Lahti and in Hollola. Mainly old oil boilers were changed, which has improved energy efficiency and cost-effectiveness. In this context, reasons why oil tanks were not renewed at the same time were not enquired. When looking at legal requirements and municipal environmental protection regulations concerning oil tanks, the renewal of an oil tank will be a time-consuming task. Also, oil tanks are estimated to have a longer technical useful life than oil boilers, therefore it is obvious that the renewals were not considered to be a current topic. During the interviews, only one mentioned that oil heating causes a risk for soil pollution but nobody recognized a risk for groundwater pollution. This was the unsatisfactory result which expresses people having inadequate knowledge of the risks regarding oil heating. This conclusion can be generalized for whole Finland.

In the second research question, it was asked why district heating would be more a interesting choice compared with oil heating. District heating has features that are clear advantages for the users compared with oil heating. Most of the interviewed oil-fired property owners valued district heating by describing it being a carefree, safe, reliable and stable heating system. There are no legal or other environmental requirements concerning the construction and the maintenance of district heating and related equipment in the households. Instead, there are many obligatory requirements concerning oil heating in the Lahti region, like regulatory inspections of all oil tanks, a ban on covering metal tanks and the placing of new oil tanks. Also, energy efficiency is at a high level with energy co-generation in the CHP plants.

In this thesis, environmental impacts between district heating and oil heating were also reviewed. Oil heating in the properties, equipped with an old oil boiler, causes nearly two times more carbon dioxide emissions to the air than district heat generation with the current fuel assortment. Furhermore, after the Kymijärvi III power plant starts up in 2021, the use of biofuels will be increased in energy generation. This supports the targets of the city of Lahti and Lahti Energy Ltd to reduce GHG emissions.

A reduction in the demand of heating oil in the residential areas supports groundwater protection in the Lahti region where large groundwater areas are located. Oil heating can basically be a safe method for heat generation, but the use requires awareness of environmental risks and regular preventative actions of oil accidents from the users.

Research questions 3 – 5 handled opportunities to expand the district heating network in the Lahti region and the cooperation between the city planners and the energy company. There is a good capacity for consumer demand to connect new buildings to the district heating network in the Lahti region. The district heat capacity is increased with the Kymijärvi II power plant since 2013. 95 % of district heat is generated in the two CHP plants, which increases the supply of district heating, and decreases the independence of natural gas. (Wallin 2014e.)

The opportunities to expand the district heating network is inspected twice a year with the city planners of the city of Lahti. The decision to build a new district heating network is resolved according to the profitability calculations produced by Lahti Energy Ltd. Discussions between the land use services of the municipality of Hollola and Lahti Energy Ltd are not implemented regularly. District heating is a less economical business for the heat supplier, especially in new and sparsely populated detached house areas, where buildings are energy efficient. The residential areas, where the district heating network exists, are interesting areas in increasing district heat consumption in a cost-effective way.

In addition to the actual research questions, the aim was to find out about oil-fired property owners' opportunities and interests in district heating. At the moment, 8 % of the respondents were interested in district heating. In these properties, all oil tanks were old and located inside an underground bunker. Also, a part of the oil boilers were old. Most of the respondents did not show interest in district heating mainly due to a long repayment period and an expensive investment. Nearly half of these respondents told that oil heating was renewed either partially or in whole.

Peoples' perceptions and understanding are not in all cases identical with the reality. According to the calculations presented in this thesis, district heating is a competitive heating system for oil-fired property owners due to investment and annual costs. The calculations apply to detached houses with an old oil boiler in residential areas, which are supplied with the district heating network in the Lahti region.

The renewal of the heating system, which is at the end of its technical useful life, will increase safety and reliability. Technical changes required are minor when changing from oil to district heat than changing to other alternative heating systems. In addition to district heating there are other methods for heat generation in residential areas available, such as wood heating, electric heating, geothermal heat and heat pumps, as well as hybrid solutions. Geothermal heat has increased its popularity, but municipal building codes may include limitations for building. The city of Lahti always requires a building permit, and the decision-making is based on a case-specific consideration in groundwater areas (Building codes of Lahti, Nastola and Kärkölä 2013, 37). A notification procedure is used in the municipality of Hollola (Building code of Hollola 2011, 4). A disadvantage of hydrid solutions is that oil heating requires regular maintenance and inspections in order to avoid oil accidents.

The results of the survey can be considered applicable, useful and significant. The response rate was high, and those interviewed were mainly interested in the topic. Questions were posed as open questions which complicated the sorting of the answers. Nevertheless, the classification of the answers succeeded despite a large number of the respondents. The research method was applicable to find out about oil-fired property owners' interests, perceptions and understanding concerning district heating. Some of the interviewed had no answer because of the open questions, yet, this method gave a better picture from the real knowledge to the researcher.

This research generated new knowledge regarding the extent of oil heating in the residential areas, which were supplied with district heating. If there is a small number of district heated buildings in old residential areas, this may be a reflection on potential customers. On the other hand, it is possible that oil heating may have been replaced with another heating system. Furthermore, the age and the condition of the oil heating systems in the survey areas are valuable information for the cooperation partner.

The study appeared successful on all research questions. Primary stress was put on questions 1 and 2, to which the answers were sought partly through the interviews. Questions 3 – 5 were studied in less detail than planned. Still, the main important results were reached. Because of the character of the study no further measures or research topics arose.

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APPENDICES

APPENDIX 1. SHARE OF FINAL ENERGY CONSUMPTION IN HOUSEHOLDS BY FUEL 2004 – 2013 IN FINLAND (STATISTICS FINLAND 2015d).

Statistikdatabaser | Statistical databases   Käyttöohjeet | PC-Axis / PX-Web   Palaute | Yhteystiedot

Tilastokeskus

Tilastokeskuksen PX-Web-tietokannat

*Tilastotietokannat > **Tietokanta:** Eurostatin avaintaulukot > Energia > Muuttujat ja luokat*

Final energy consumption in households by fuel

Muokkaa ja laske   Tallenna   Kuviot ja kartat

Pikalinkit: XLS PX CSV

Final energy consumption in households by fuel muuttujina geo, product ja time

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Suomi										
Solid fuels	0,2	0,2	0,2	0,2	0,1	0,1	0,1	0,1	0,1	0,1
Total petroleum products	14,3	13,8	13,3	12,7	9,9	9,5	9,4	8,0	8,0	7,6
Gas	0,6	0,6	0,7	0,7	0,8	0,8	0,8	0,6	0,6	0,6
Derived heat	28,8	28,3	28,4	28,7	29,3	29,6	30,0	29,8	30,6	30,9
Renewable energies	21,7	21,9	22,0	22,2	25,1	25,3	25,8	25,2	25,3	24,5
Electrical energy	34,4	35,1	35,4	35,6	34,8	34,7	33,9	36,3	35,4	36,3

Residential.
Percentage.

Eurostatin kotisivu
Eurostat taulukkokoodi: t2020_rk210

Eurostat vastuuvapauslauseke

Viimeksi päivitetty:
2015-02-04 00:00

Lähde:
Eurostat

Tekijänoikeus:
Suojattu

Yhteystiedot:
Sähköposti: tietokannat@tilastokeskus.fi
Puhelin: +358 2955 2354

Mittayksikkö:
none

Tilastokeskus • Vaihde 029 551 1000 • Yhteystiedot • Tekijänoikeudet • Palaute

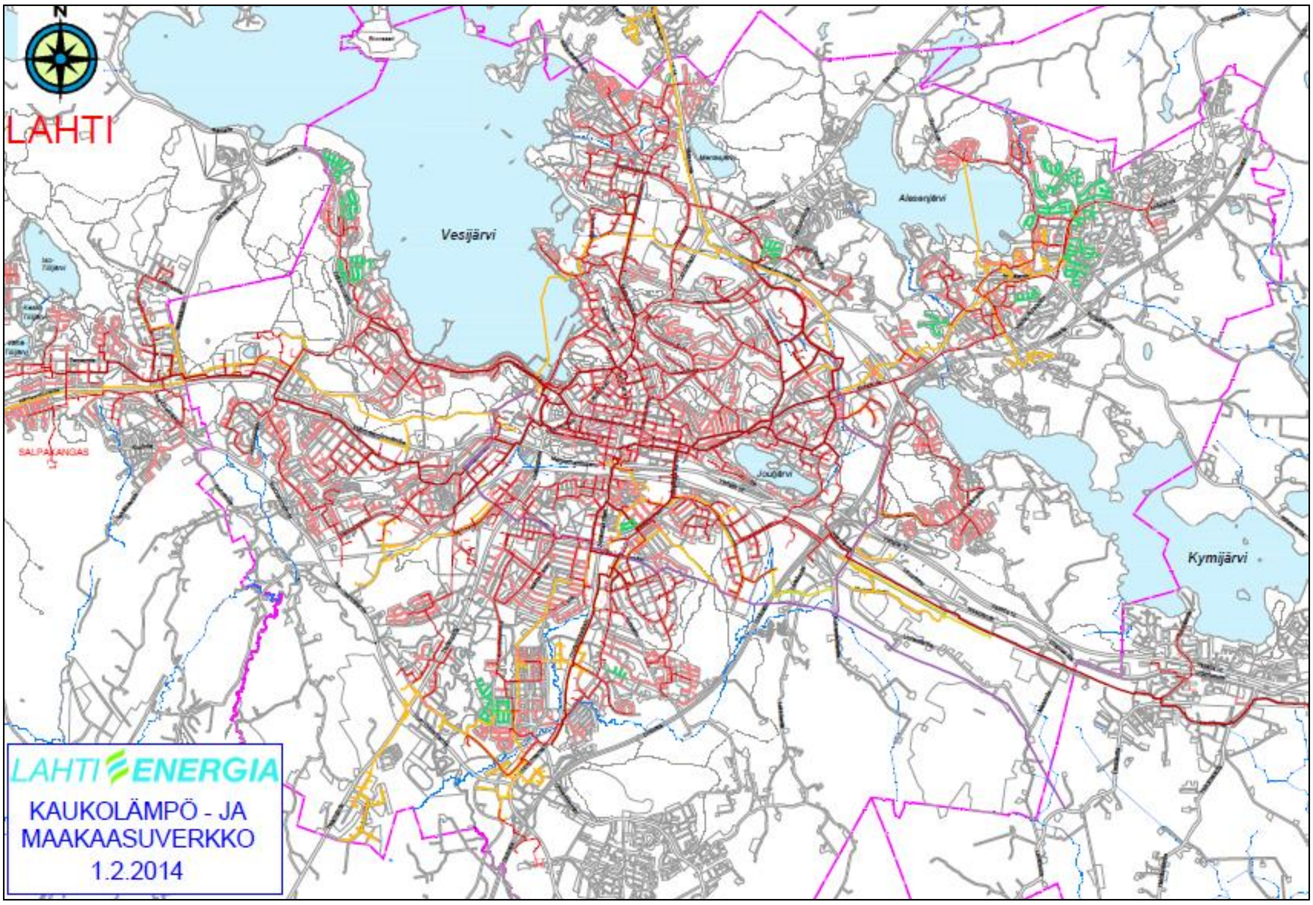
APPENDIX 2. HEATING ENERGY CONSUMPTION IN HOUSEHOLDS BY ENERGY SOURCE IN 2013, GWH (STATISTICS FINLAND 2015e).

	Heating of residential buildings		- Detached houses		- Terraced houses		- Blocks of flats		Free-time residential buildings	
	Total, GWh	Total, %	Total, GWh	Total, %	Total, GWh	Total, %	Total, GWh	Total, %	Total, GWh	Total, %
Wood	14502	26.3 %	12571	39.9 %	149	2.7 %	90	0.6 %	1692	64.2 %
Peat	49	0.1 %	42	0.1 %	1	0.0 %	5	0.0 %	1	0.0 %
Coal	3	0.0 %	3	0.0 %	-	0.0 %	-	0.0 %	0	0.0 %
Heavy fuel oil	87	0.2 %	-	0.0 %	-	0.0 %	87	0.6 %	-	0.0 %
Light fuel oil	4357	7.9 %	3432	10.9 %	278	5.0 %	595	3.8 %	52	2.0 %
Natural gas	336	0.6 %	99	0.3 %	77	1.4 %	159	1.0 %	1	0.0 %
Ambient energy 1)	4262	7.7 %	3757	11.9 %	358	6.5 %	30	0.2 %	117	4.4 %
District heating	18312	33.2 %	2053	6.5 %	2884	52.1 %	13372	86.4 %	2	0.1 %
Electricity 2)	13234	24.0 %	9536	30.3 %	1791	32.3 %	1134	7.3 %	772	29.3 %
Total	55143	100.0 %	31493	100.0 %	5538	100.0 %	15472	100.0 %	2637	100.0 %
Explanation of symbols: - = Magnitude zero, 0 = Magnitude less than half unit employed										

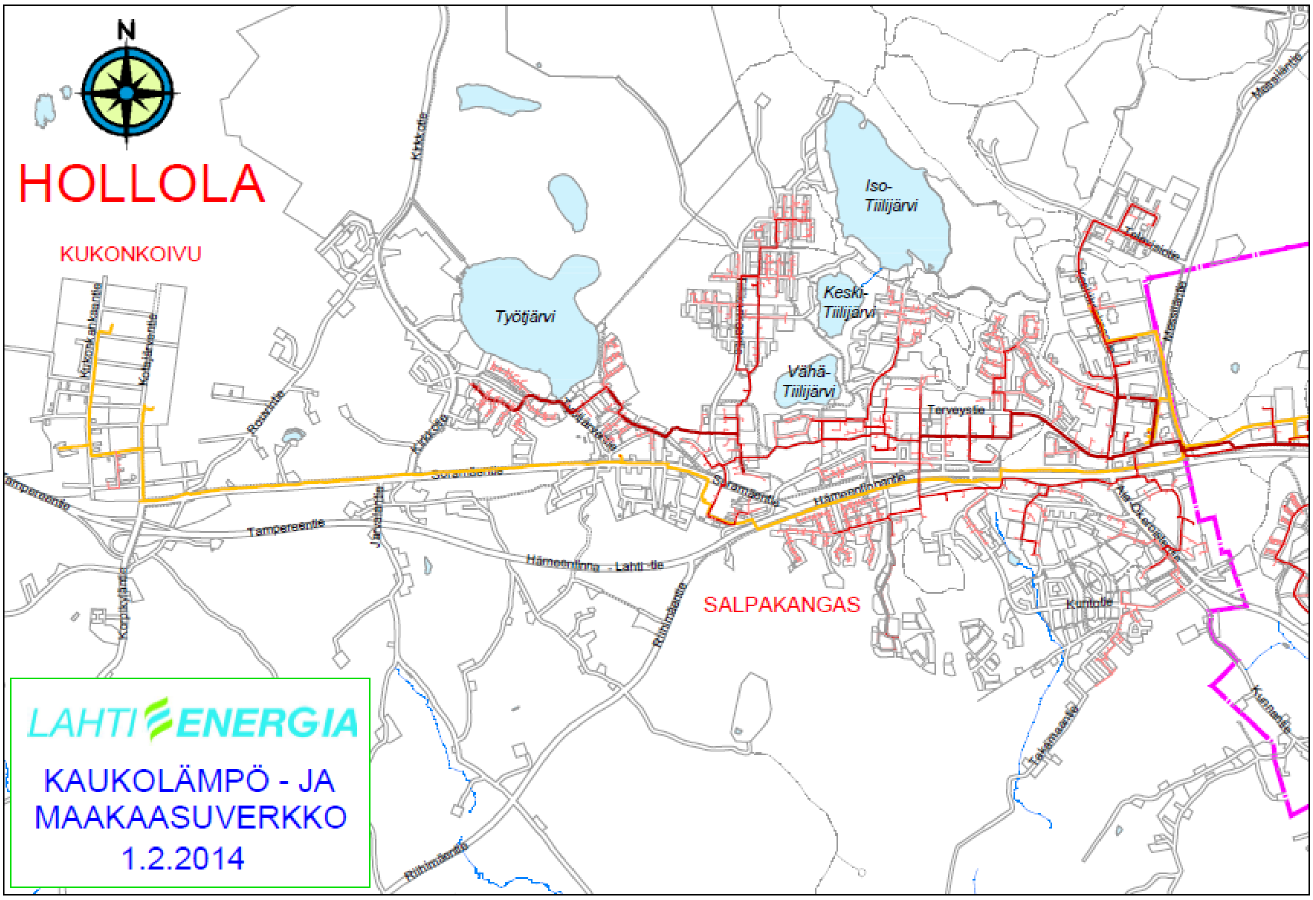
1) Ambient energy refers to energy extracted with heat pumps from the environment (ground, air or water) for space heating. Electricity spent by heat pumps in heating and cooling use is included in the electricity consumption of heating.

2) Electrical heating of residential buildings includes direct electrical heating, electric storage heating, additional heating and floor heating by electricity, the electricity used by heat pumps, the heating of domestic water by electricity, electric sauna stoves and the electricity consumed by the heating systems and the heat distribution equipment.

APPENDIX 3. DISTRICT HEATING NETWORK IN THE CITY OF LAHTI (LAHTI ENERGY 2014b).



APPENDIX 4. DISTRICT HEATING NETWORK IN THE MUNICIPALITY OF HOLLOLA (LAHTI ENERGY 2014b).



APPENDIX 5. ORIGINAL SURVEY QUESTIONNAIRE (IN FINNISH)

Kyselylomake: haastattelupäivä:________________________

1.Nimi ja ikä (alle 30, 30-50, yli 50)
2. Katuosoite
3. Säiliön tilavuus
4. Säiliön sijainti
5. Säiliön materiaali
6. Säiliön kuntoluokka
7. Viimeisin tarkastusajankohta
8. Säiliön asennusvuosi
9. Öljykattilan ikä ja kunto
10. Vuotuinen öljyn kulutus
11. Onko tarjottu viime vuosina liittymistä kaukolämpöön
12. Onko nyt harkinnut liittymistä kaukolämpöön? kyllä / ei, syy:
13. Mielikuva kaukolämmöstä lämmitysmuotona
14. Käsitys kaukolämmön taloudellisuudesta
15. Käsitys muutosinvestoinnin kokoluokasta ja kannattavuudesta
16. Mielikuva kaukolämmön ympäristöystävällisyydestä verrattuna öljylämmitykseen

APPENDIX 6. EXAMPLES OF INITIAL ANSWERS (IN FINNISH)

Ten different kind of the answers are listed to the table.

	Haastattelun tiedot				Öljysäiliön tiedot						Kattilan ja öljynkulutuksen tiedot	
nro	pv	Mies, nainen	alle 30 v 30-50 v yli 50 v	Alue	Tilavuus litroina	Sijainti	Mate-riaali	Kunto-luokka: A, B, C, D	Tarkas-tettu viimeksi	Asennus-vuosi	Öljykattilan ikä / kunto	Vuotuinen öljyn kulutus, litroina
1	16.6.2014	Mies	yli 50	Hollola	3000	säiliö-huoneessa	teräs	N/a	useita vuosia sitten	1978	kattila uusittu 2003-2004 (a)	1500
2	9.6.2014	Mies	yli 50	Hollola	3000	säiliö-huoneessa	muovi	-	ei tarkas-tettu	1978	alkuperäinen, 1978	2000
3	9.6.2014	Mies	yli 50 (a)	Hollola	3000	maan alla bunkkerissa	teräs	N/a	2010-2012 (a)	1979	alkuperäinen, 1979	2000
4	12.6.2014	Mies	yli 50 (a)	Hollola	1500	säiliö-huoneessa	muovi	ei rele-vantti	ei rele-vantti	2007	kattila uusittu 2004 (n. 10 v sitten)	2500
5	1.9.2014	Mies	yli 50 (a)	Lahti	1800	maan alla bunkkerissa	muovi	-	ei tarkas-tettu	2002	kattila uusittu 2009	1500-1700
6	29.9.2014	Nainen	30-50	Lahti	3000	maan alla bunkkerissa	teräs	A	2014	1973	kattila uusittu (aika: N/a)	N/a
7	8.5.2014	Mies	yli 50	Hollola	3000	säiliö-huoneessa	teräs	B	2011	1969	alkuperäinen, 1969	2800
8	9.9.2014	Mies	30-50	Lahti	3000	maan alla bunkkerissa	teräs	N/a	2011	1970	kattila uusittu 2012	3000
9	23.5.2014	Nainen	yli 50	Hollola	3000	maan alla bunkkerissa	teräs	B	2012	1976	kattila uusittu, 2000	2500
10	9.9.2014	Nainen	yli 50	Lahti	5000	maan alla bunkkerissa	teräs	A	N/a (muuta ma vuosi sitten)	1971	1971 (alkuper.)	1800

	Kaukolämpöä koskevat kysymykset					
nro	Onko tarjottu liittymistä kaukolämpöön viime vuosina	Onko nyt harkinnut liittymistä kaukolämpöön: kyllä/ei (syy)	Mielikuva kaukolämmöstä lämmitys-muotona	Käsitys kaukolämmön taloudellisuudesta	Käsitys muutos-investoinnin kokoluokasta ja kannattavuudesta	Mielikuva kaukolämmön ympäristöystävällisyydestä verrattuna öljylämmitykseen
1	ei	Ei, koska uusittu kattila ja öljynkulutus vähäinen	Hyvä	Monopoliasema määrittelee hinnan, osinkojen maksu vaikuttaa kauko-lämmön hintaan	20 000 - 25 000 €	On ympäristöystävällisempää, tosin öljyt ovat nykyään puhtaita
2	on (2014)	Ei, koska nykyisellä öljyn kulutuksella pitkä takaisin-maksuaika	Hyvä (ratkaisu)	On taloudellinen	10 000 €	On ympäristöystävällisempää
3	on (2014)	Kyllä, vaihtoehtoisesti kattilan uusiminen	Hyvä, helppo. Ei voi kilpailuttaa (monopoli)	Hieman halvempi kuin öljy	8 000 €	Päästöt keskittyy (asuinalueen ilmapäästöjen vähentyminen)
4	on	Ei, koska kattila ja säiliö uusittu	Helppo, huoleton	Hieman edullisempi kuin öljy	Ei käsitystä	Ehkä paljon ympäristöystävällisempää, kun päästöjä ei tule asuinalueelle
5	on (viimeksi 2014)	Ei, koska kattila ja säiliö uusittu	Huoleton	Hieman edullisempi kuin öljy	8 000 €	Ehkä hieman ympäristö-ystävällisempää. Öljy nykyään puhdasta ja uuden kattilan hyötysuhde tasolla 95 %
6	ei	Ei, koska kattila uusittu ja säiliö kunnossa	Positiivinen, helppo, vaivaton	Voi olla edullisempi (kuin öljy)	10 000 €	On ympäristöystävällisempää
7	on	Ei, koska hinta noussut. Varattu muovisäiliö asennettavaksi	Huolettomampi (kuin öljy)	Ei eroa öljylämmitykseen	10 000 €	Ei vastausta
8	ei	Kyllä, kaukolämpö (ja maakaasu) kiinnostaa	Vaivaton	Samalla tasolla kuin öljy	8 000 €	Kaukolämpö on ympäristöystävällisempää
9	ei	Ei, koska kattila uusittu.	Neutraali, ei sen parempi kuin öljy	Vähän kalliimpi kuin öljy	10 000 €	Ei eroa
10	on kauko-lämpöverkon rakennusvai-heessa ja sen jälkeen	Ei, koska kallis investointi	Ei käsitystä	Kaukolämmön hinta nousee koko ajan	Ei käsitystä	On hyvä vaihtoehto öljylämmitykselle

APPENDIX 7. THE ANNUAL COSTS AND THE ANNUAL CO_2 EMISSIONS OF OIL HEATING CALCULATED AT THE INTERVIEW MOMENT IN 2014; AND IN THE SITUATION, WHERE THE ENERGY USE IS GENERATED WITH DISTRICT HEAT INSTEAD OF OIL HEATING.

CASE 1: Oil consumption 2000 litres per year

Calculation time: **May-September 2014**

1970s detached house including an original oil boiler

Oil heating, annual costs	
Annual oil consumption, litres	**2000**
Oil consumption, tonnes	1.69
Price of oil, €	1.04
Oil total €, year	2080
Sweeping of flue, €	40
Sweeping of oil boiler, €	50
Oil burner service, €	150
Oil heating total €, year	**2320**
Efficiency of oil boiler	0.72
Default net calorific value, GJ/tonnes	43
Calorific value, GJ	52.32
Calorific value **(energy use)**, MWh	14.53
Oil heating, annual CO2 -emissions	
Oil consumption, m3	2
Density, t/m3	0.845
CO_2 emission factor, t/TJ	74
Oxidation factor	0.995
Net calorific value GJ/t	43
Oil heating total, annual t CO2	**5.3**
District heating, annual costs	
Calorific value, MWh	14.53
Price of district heating, €/MWh	85.19
District heating total €, year	**1238**
District heating, annual CO2 -emissions	
Specific emission factor, g CO2/kWh	189.8
District heating total, annual t CO2	**2.8**

APPENDIX 8. THE ANNUAL COSTS AND THE ANNUAL CO_2 EMISSIONS OF OIL HEATING CALCULATED AT THE REFERENCE DATE IN 2015; AND IN THE SITUATION, WHERE THE ENERGY USE IS GENERATED WITH DISTRICT HEAT INSTEAD OF OIL HEATING.

CASE 2: Oil consumption 2000 litres per year

Calculation time:	**February 2015**

1970s detached house including an original oil boiler

Oil heating, annual costs	
Annual oil consumption, litres	**2000**
Oil consumption, tonnes	1.69
Price of oil, €	0.93
Oil total €, year	1860
Sweeping of flue, €	40
Sweeping of oil boiler, €	50
Oil burner service, €	150
Oil heating total €, year	**2100**
Efficiency of oil boiler	0.72
Default net calorific value, GJ/tonnes	43
Calorific value, GJ	52.32
Calorific value **(energy use)**, MWh	14.53

Oil heating, annual CO2 -emissions	
Oil consumption, m3	2
Density, t/m3	0.845
CO_2 emission factor, t/TJ	74
Oxidation factor	0.995
Net calorific value GJ/t	43
Oil heating total, annual t CO2	**5.3**

District heating, annual costs	
Calorific value, MWh	14.53
Price of district heating, €/MWh	87.16
District heating total €, year	**1267**

District heating, annual CO2 -emissions	
Specific emission factor, g CO2/kWh	189.8
District heating total, annual t CO2	**2.8**

APPENDIX 9. THE ANNUAL COSTS AND THE ANNUAL CO_2 EMISSIONS OF OIL HEATING CALCULATED AT THE INTERVIEW MOMENT IN 2014; AND IN THE SITUATION, WHERE THE ENERGY USE IS GENERATED WITH DISTRICT HEAT INSTEAD OF OIL HEATING.

CASE 3: Oil consumption 3000 litres per year

Calculation time:	**May-September 2014**
1970s detached house including an original oil boiler	
Oil heating, annual costs	
Annual oil consumption, litres	**3000**
Oil consumption, tonnes	2.535
Price of oil, €	1.04
Oil total €, year	3120
Sweeping of flue, €	40
Sweeping of oil boiler, €	50
Oil burner service, €	150
Oil heating total €, year	**3360**
Efficiency of oil boiler	0.72
Default net calorific value, GJ/tonnes	43
Calorific value, GJ	78.48
Calorific value **(energy use)**, MWh	21.80
Oil heating, annual CO2 -emissions	
Oil consumption, m3	3
Density, t/m3	0.845
CO_2 emission factor, t/TJ	74
Oxidation factor	0.995
Net calorific value GJ/t	43
Oil heating total, annual t CO2	**8.0**
District heating, annual costs	
Calorific value, MWh	21.80
Price of district heating, €/MWh	85.19
District heating total €, year	**1857**
District heating, annual CO2 -emissions	
Specific emission factor, g CO2/kWh	189.8
District heating total, annual t CO2	**4.1**

APPENDIX 10. THE ANNUAL COSTS AND THE ANNUAL CO_2 EMISSIONS OF OIL HEATING CALCULATED AT THE REFERENCE DATE IN 2015; AND IN THE SITUATION, WHERE THE ENERGY USE IS GENERATED WITH DISTRICT HEAT INSTEAD OF OIL HEATING.

CASE 4: Oil consumption 3000 litres per year

Calculation time:	**February 2015**
1970s detached house including an original oil boiler	
Oil heating, annual costs	
Annual oil consumption, litres	**3000**
Oil consumption, tonnes	2.535
Price of oil, €	0.93
Oil total €, year	2790
Sweeping of flue, €	40
Sweeping of oil boiler, €	50
Oil burner service, €	150
Oil heating total €, year	**3030**
Efficiency of oil boiler	0.72
Default net calorific value, GJ/tonnes	43
Calorific value, GJ	78.48
Calorific value **(energy use)**, MWh	21.80
Oil heating, annual CO2 -emissions	
Oil consumption, m3	3
Density, t/m3	0.845
CO_2 emission factor, t/TJ	74
Oxidation factor	0,995
Net calorific value GJ/t	43
Oil heating total, annual t CO2	**8.0**
District heating, annual costs	
Calorific value, MWh	21.80
Price of district heating, €/MWh	87.16
District heating total €, year	**1900**
District heating, annual CO2 - emissions	
Specific emission factor, g CO2/kWh	189.8
District heating total, annual t CO2	**4.1**

APPENDIX 11. THEORETICAL ESTIMATION OF OIL PRICE IN THE SITUATION, WHERE THE ANNUAL COSTS OF OIL HEATING AND DISTRICT HEATING ARE AT THE SAME LEVEL IN 2015.

CASE 5: Oil consumption 2000 litres per year

Calculation time:	**February 2015**
1970s detached house including an original oil boiler	
Oil heating, annual costs	
Annual oil consumption, litres	**2000**
Oil consumption, tonnes	1.69
Price of oil, €	**0.51**
Oil total €, year	1020
Sweeping of flue, €	40
Sweeping of oil boiler, €	50
Oil burner service, €	150
Oil heating total €, year	**1260**
Efficiency of oil boiler	0.72
Default net calorific value, GJ/tonnes	43
Calorific value, GJ	52.32
Calorific value **(energy use)**, MWh	14.53
District heating, annual costs	
Calorific value, MWh	14.53
Price of district heating, €/MWh	87.16
District heating total €, year	**1267**

APPENDIX 12. THEORETICAL ESTIMATION OF OIL PRICE IN THE SITUATION, WHERE THE ANNUAL COSTS OF OIL HEATING AND DISTRICT HEATING ARE AT THE SAME LEVEL IN 2015.

CASE 6: Oil consumption 3000 litres per year

Calculation time:	**February 2015**
1970s detached house including an original oil boiler	
Oil heating, annual costs	
Annual oil consumption, litres	**3000**
Oil consumption, tonnes	2.535
Price of oil, €	**0.551**
Oil total €, year	1653
Sweeping of flue, €	40
Sweeping of oil boiler, €	50
Oil burner service, €	150
Oil heating total €, year	**1893**
Efficiency of oil boiler	0.72
Default net calorific value, GJ/tonnes	43
Calorific value, GJ	78.48
Calorific value **(energy use)**, MWh	21.80
District heating, annual costs	
Calorific value, MWh	21.80
Price of district heating, €/MWh	87.16
District heating total €, year	**1900**

APPENDIX 13. THEORETICAL ESTIMATION OF THE ANNUAL COSTS AND THE ANNUAL CO_2 EMISSIONS IN THE DETACHED HOUSE SUPPLIED WITH A NEW OIL BOILER; AND IN THE SITUATION, WHERE THE ENERGY USE IS GENERATED WITH DISTRICT HEAT INSTEAD OF OIL HEATING.

CASE 7: Detached house including a new oil boiler

Calculation time: **February 2015**

Oil heating, annual costs	
Annual oil consumption, litres	**2350**
Oil consumption, tonnes	1.99
Price of oil, €	**0.93**
Oil total €, year	2186
Sweeping of flue, €	40
Sweeping of oil boiler, €	50
Oil burner service, €	150
Oil heating total €, year	**2426**
Efficiency of oil boiler	**0.92**
Default net calorific value, GJ/tonnes	43
Calorific value, GJ	78.56
Calorific value (energy use), MWh	21.82
Oil heating, annual CO2 -emissions	
Oil consumption, m3	2.35
Density, t/m3	0.845
CO_2 emission factor, t/TJ	74
Oxidation factor	0.995
Net calorific value GJ/t	43
Oil heating total, annual t CO2	**6.2**

District heating, annual costs	
Calorific value, MWh	21.82
Price of district heating, €/MWh	87.16
District heating total €, year	**1902**

District heating, annual CO2 -emissions	
specific emission factor, g CO2/kWh	189.8
District heating total, annual t CO2	**4.1**

APPENDIX 14. THEORETICAL ESTIMATION OF THE ANNUAL CO_2 EMISSIONS OF DISTRICT HEATING IN WHOLE SURVEY AREA; AND IN THE SITUATION, WHERE THE ENERGY USE IS GENERATED WITH DISTRICT HEAT INSTEAD OF OIL HEATING.

Calculation time:	**May-September 2014**

89% of the respondents reported annual oil consumption.

Oil heating, annual costs	
Annual oil consumption, litres	**120000**
Oil consumption, tonnes	101.4
Efficiency of oil boiler	0.8
Default net calorific value, GJ/tonnes	43
Calorific value, GJ	3488.16
Calorific value **(energy use)**, MWh	968.93

Oil heating, annual CO2 -emissions	
Oil consumption, m3	120
Density, t/m3	0.845
CO_2 emission factor, t/TJ	74
Oxidation factor	0.995
Net calorific value GJ/t	43
Oil heating total, annual t CO2	**321.0**

District heating, annual CO2 -emissions	
Specific emission factor, g CO2/kWh	189.8
District heating total, annual t CO2	**183.9**